AD-A132 111 COMPARE: A METHOD FOR ANALYZING INVESTMENT ALTERNATIVES IN INDUSTRIAL WOOD AND BARK ENERGY SYSTEMS(U) FOREST PRODUCTS LAB MADISON WI P J INCE JUN 83 FSGTR-FPL-36 1/2

UNCLASSIFIED F/G 21/4 NL

United States
Department of
Agriculture

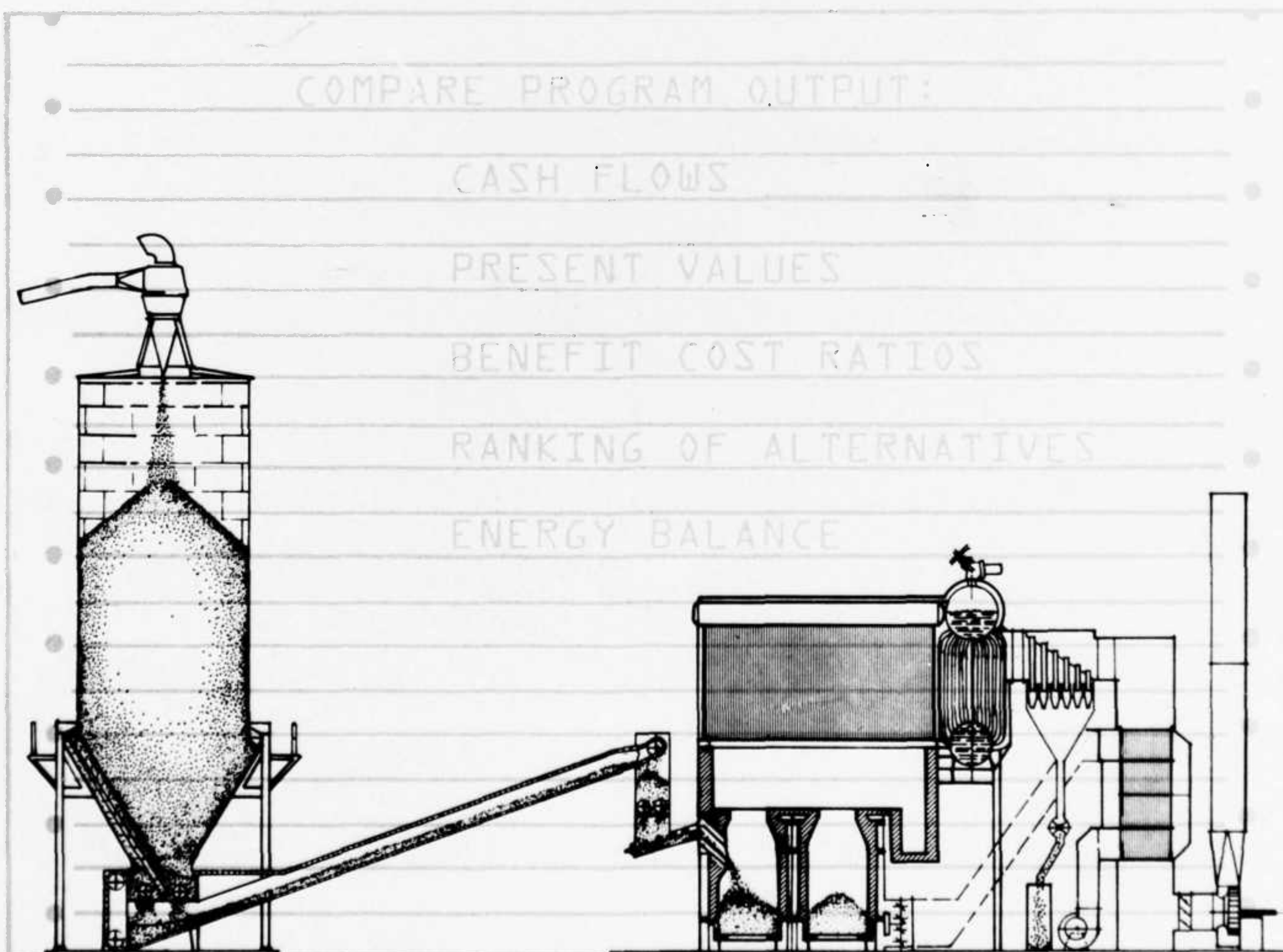
Forest Service

Forest
Products
Laboratory

General
Technical
Report
FPL-36

COMPARE
A Method for Analyzing Investment Alternatives in Industrial Wood and Bark Energy Systems

Peter J. Ince



Abstract

COMPARE is a FORTRAN computer program resulting from a study to develop methods for comparative economic analysis of alternatives in industrial wood and bark energy systems. COMPARE provides complete guidelines for economic analysis of wood and bark energy systems. As such, COMPARE can be useful to those who have only basic familiarity with investment analysis of wood and bark energy systems. This report provides instructions on how to prepare data for COMPARE, information on how to use the program, sample data, sample output, and a listing of the program.

COMPARE ranks investment alternatives according to the highest benefit cost ratio based on discounted energy values and cash flows. The use of a benefit cost ratio as a ranking criterion is analyzed and explained in an appendix to this report.

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June 1983

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PETER J. INCE, Research Forester

Introduction

This report presents a method that was developed to analyze investments in industrial wood and bark energy systems. The method is embedded in a computer program called COMPARE that is presented in this report.

COMPARE was written in FORTRAN language which is widely used among forest products researchers and professionals. COMPARE was developed using facilities of the University of Wisconsin UNIVAC 1110 computer under the EXEC 8 operating system, and is compatible with the Madison Academic Computer Center version of the FORTRAN V language.

This report contains instructions for others who woulo like to use COMPARE. A user must have access to a computer system capable of processing the COMPARE program listed in the appendix. Since all versions of FORTRAN and all computer systems are not precisely the same, some minor modifications may be required in the program to make COMPARE compatible with other systems. A user should have some experience or basic familiarity with FORTRAN computer programs, with cash flow investment analysis, and with the general design or concepts of industrial energy systems that burn wood or bark as fuel. Several references are provided for general information on cash flow analysis (*1, 2, 7, 8*),[2] concepts of wood energy systems (*3, 5*), and computer programs for economic analysis (*4, 6*). Finally, the user will create the required data which are used as input for COMPARE and described in this report. COMPARE is therefore an analytical tool, the results of which depend mainly on data provided by the user.

COMPARE is a framework for economic investment analysis of alternatives in wood and bark energy systems. The user of COMPARE provides a set of data which describes two or more investment alternatives. With accurate data, COMPARE will calculate which alternative appears most economical. The following are some examples of applications where COMPARE may be useful:

1. An economic feasibility study of a new wood or bark energy system at a manufacturing plant.
2. A comparative economic analysis of using wood or bark fuel versus "fossil" fuel (e.g. coal, oil, or gas) at an industrial facility.
3. An economic feasibility study of adding new equipment to an existing wood or bark energy system (such as fuel predryers or additional heat recovery devices).
4. Research and development economic analyses of new wood and bark energy systems or new equipment design concepts.

[1]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2]Italicized numbers in parentheses refer to literature cited at the end of this report.

Program Function

A complete listing of the COMPARE program is provided in the appendix. Overall, COMPARE performs the following series of data processing and analytical steps:

READ DATA SUPPLIED BY USER AND ASSIGN PROGRAMED DATA

FOR EACH ALTERNATIVE:

CALCULATE DEPRECIATION ALLOWANCES

CALCULATE HEAT ENERGY RECOVERY

CALCULATE FUEL REQUIREMENTS

CALCULATE INVESTMENT PARAMETERS AND ECONOMIC CRITERIA

PRINT:
FINANCIAL SUMMARIES
RANKING OF ALTERNATIVES
ENERGY, FUEL PARAMETERS

First, COMPARE reads the data input supplied by the user, and assigns programed data values for the analysis.

The program then calculates depreciation for each investment alternative being analyzed. In data input the user can specify the depreciation schedule that will be calculated from the four schedules that are mandated under the Federal Accelerated Cost Recovery System—ACRS (1981). The choice of schedule depends on when the investment is put in place. The first schedule applies in 1981 to 1984, the second schedule applies in 1985, and the third schedule applies in 1986 and thereafter. The fourth schedule is straight line depreciation which can be used at any time under ACRS guidelines. Alternatively, the user can simply enter a complete depreciation schedule as data input instead of having the schedule calculated by the program.

Next, the program calculates heat recovery in Btu per pound of wood or bark fuel for each alternative. Heat recovery estimates are calculated on the basis of data input. The general algorithm for calculating heat recovery is described in a separate publication (*5*).

The program then calculates the quantity of wood or bark, as well as alternate or auxiliary fuels (nonwood or bark) required to satisfy user-specified annual heat requirements in each of the investment alternatives.

Next, the program calculates net cash flows and present value of net cash flows for each alternative. Net cash flow is conventionally defined as revenues minus operating expenses, taxes, and investments in a given time period. However, COMPARE only considers operating expenses (costs), taxes, and investment. COMPARE operates on the assumption that there are always sufficient revenues and tax liability, such that the full amount of depreciation allowances and expenses can be deducted from tax liability. Thus, in COMPARE the annual "net cash flows" are calculated as follows: The initial net cash flow occurs at the beginning of the first year (beginning of year 1, also known as "year 0"). The initial net cash flow is the old facility net salvage value, minus the total initial investment and working capital requirement. Subsequent cash flows are end of year flows. Net cash flow at the end of the first year is investment tax credit, plus first year depreciation allowance times the tax rate, minus additional investment (for working capital), and annual costs (including the nondepreciable expenses part of investment) times one minus the tax rate. Net cash flows for subsequent years are calculated as depreciation allowance times tax rate, minus additional investment, and annual costs times one minus the tax rate. Net cash flow for the last year is adjusted by adding back the accumulated working capital and ending salvage value.

The program then calculates a benefit cost ratio for each investment alternative. The benefit part of the ratio is the discounted present value of energy outputs which are assigned an arbitrary value by the user. The "cost" part is the discounted present value of net cash flows. In COMPARE, net cash flows represent essentially the net cost of energy, after taking into account investment, taxes, and depreciation. Energy output values are assigned in the data input in dollars per million Btu. The methodology and appropriateness of using a benefit cost ratio as a criterion is discussed in the appendix.

Finally, the program calculates the heat energy and fuel requirements balance for each alternative in terms of Btu and fuel sales units.

Data Requirements

COMPARE data input requirements are described in this section of the report. Data input is partly optional because COMPARE contains programed values for part of the data. The programed values are for data that can be assigned typical or common values. For example, the higher heating value of wood or bark is assigned a

value of 8,500 Btu per pound. The user may always refine an analysis by entering more accurate data to replace the programed values. The user may replace programed values by simply entering different values in the data. However, COMPARE does not contain programed values for some of the data (particularly economic data) so the user must always provide some of the data for program input.

The first step in using COMPARE is to create the data set for each of the investment alternatives. From 2 to 10 alternatives can be analyzed per run. It is an important and critical task for the user to create accurate data because the accuracy of results is likely to depend on the accuracy of the data.

The first items of data required for COMPARE are the number of alternatives to be analyzed and a name or title for each alternative. Next, data are required on the physical parameters of wood and bark, and alternate or auxiliary (nonwood or bark) fuels in each alternative. The data should represent average values, and are intended to describe the average physical characteristics of fuels in each of the alternatives. Table 1 describes the specific data that are required for each alternative. As indicated in table 1, the COMPARE program is provided with programed values for most of the data. Thus, the user does not need to provide data if programed values are appropriate. Table 1 shows the specific values that are programed for all alternatives. As noted in table 1, the user must provide some data for which there are no programed values. A set of data corresponding to the data outlined in table 1 must be entered for each of the investment alternatives. Table 1 also gives the program name (four-letter variable code) for each of the items of data.

Data are required also on the physical parameters of the heat recovery system for each alternative. Those parameters are shown in table 2 as are the programed values that will be used for all alternatives unless the user provides substitute data. A separate set of data corresponding to that shown in table 2 must be developed for each investment alternative.

Table 1. — Description of data input parameters required by COMPARE for wood or bark fuel and auxiliary or alternate fuel for each investment alternative.

Parameter description	Programed value[1]				Program variable name
(1) wood or bark fuel moisture content (as fired, average decimal fraction of wet weight)	([2])				AFMC
(2) weight of wood or bark fuel in ovendry pounds per sales unit	([2])				AWRU
(3) the name of the wood or bark fuel sales unit (maximum of 8 letters)	([2])				RFS1 and RFS2
(4) the ultimate analysis hydrogen content of the wood or bark fuel (decimal fraction of dry weight)	0.06				AVHC
(5) the ultimate analysis oxygen content of the wood or bark fuel (decimal fraction of dry weight)	0.41				AVOC
(6) the ultimate analysis carbon content of the wood or bark fuel (decimal fraction of dry weight)	0.50				AVCC
(7) the ultimate analysis nitrogen content of the wood or bark fuel (decimal fraction of dry weight)	0.01				AVNC
(8) average higher heating value of the wood or bark fuel (Btu per pound, ovendry)	8,500.0				AHHV
(9) type of alternate or auxiliary fuel (coded choice: 0-oil, 1-coal, 2-nat. gas, 3-other)	*(0)*	*(1)*	*(2)*	*(3)*	NCAF
(10) the name of the alternate or auxiliary fuel (max. of 4 letters)	OIL	COAL	GAS	([2])	AXFT
(11) the name of the sales unit for the alternate or auxiliary fuel (4 letters)	BBL.	TON	MCF	([2])	AFSU
(12) higher heating value of alternate or auxiliary fuel (millions of Btu per sales unit)	6.3	24.0	1.0	([2])	HHVU
(13) combustion heat recovery efficiency obtained from alternate or auxiliary fuel (decimal fraction of higher heating value)	0.8	0.67	0.76	([2])	CHRE

[1]Programed values are used in the analysis unless the user enters substitute data.

[2]Indicates parameter must be supplied by user (no programed value).

Table 2. — Description of data input parameters required by COMPARE for the heat recovery system in each alternative

Heat recovery system parameters		
Parameter description	Programed value[1]	Program variable name
(14) essential annual heat energy requirements, or essential heat energy output of the system in millions of Btu per year	[2]	EBTU
(15) surplus heat energy output in millions of Btu per year	[2]	SBTU
(16) maximum quantity of wood or bark fuel available for use per year (sales units)	[2]	RAVL
(17) temperature of flue or stack gases just beyond heat recovery devices of the system when burning wood or bark fuel (°F)	500.0	ASGT
(18) temperature of the wood or bark fuel entering the furnace (°F)	60.0	ATRF
(19) temperature of the combustion air entering the furnace (°F) with wood or bark	60.0	ATCA
(20) excess air entering the furnace, as a decimal fraction of theoretical air needed for combustion, when burning wood or bark	0.40	AEAF
(21) "conventional" heat loss (decimal fraction of available heat of combustion that is lost via radiation, convection, conduction, etc.), when burning wood or bark	0.04	ACHL
(22) the decimal fraction of Btu output which is designed to be derived from wood or bark fuel when such fuel is available and used (remaining fraction is derived from auxiliary fuel)	0.0	AFBA

[1]Programed values are used unless the user enters substitute data.

[2]Indicates parameter must be supplied by user (no programed values).

Finally, data are required on the economic parameters, for which there are no programed values, associated with each alternative. Table 3 outlines the required economic data, all of which must be entered by the user. A separate set of data corresponding to that shown in table 3 must be provided for each investment alternative.

The data outlined in tables 1 to 3 describe fully the pertinent physical and economic parameters of each alternative. There must be a title and a set of data corresponding to the data outlined in tables 1 to 3 for each alternative.

A Compare Analysis Example

The following is an example of analysis using the COMPARE program based on hypothetical sample data. Three investment alternatives in energy systems for a hypothetical forest products manufacturing facility are compared. The first is to continue operating a fully depreciated boiler system that uses natural gas fuel and requires no new investment. The second, requiring an investment of $1,428,000, is to install a wood fuel and supplementary oil burning furnace and boiler to burn available wood residues. The third alternative is to install a larger wood fuel and coal burning furnace and boiler requiring an investment of $1,828,000. The second and third alternatives allow surplus heat energy output.

Under all three alternatives, the energy system will satisfy the essential process heat energy requirements of the wood products facility. Heat energy is required, for example, as process steam and for space heating. Essential heat energy requirements are 252,230 million Btu per year. The critical question is, which of the three investment alternatives is most economical? Sufficient data have been obtained to use the COMPARE program to analyze the three alternatives. The sample data and analysis results are provided here. Again, this is purely an illustrative example. Results are not applicable in general to other cases.

Data Input Format

The sample data illustrated in figure 1 describe each of the three investment alternatives. Data input is prepared for COMPARE using specific data format and instructions described in this section of the report. The data include the number of investment alternatives, the

Table 3. — Description of economic data parameters required by COMPARE

Economic parameters	
Parameter description	**Program variable name**
(23) the capital investment in new assets required to undertake the investment alternative or project (in dollars at the beginning of the first year of the planning period—year 0)	IVST
(24) the working capital requirements needed to undertake the project (dollars required at year 0)	WCRQ
(25) the nondepreciable expenses required to undertake the project (dollars at year 0)	IEXP
(26) the salvage value, if any, from salvage of old assets (in dollars, after taxes, at year 0)	CSAL
(27) the after-tax salvage value of new assets at the end of the last year of the planning period (in dollars)	FATS
(28) the discount rate used for discounting future after-tax net cash flows to present value (decimal fraction)	DISR
(29) the effective tax rate on ordinary income (decimal fraction)	TXRT
(30) depreciation schedule for new assets (coded choice: 1—ACRS schedule for 1981 to 1984, 2—ACRS schedule for 1985, 3—ACRS schedule for 1986 and thereafter, 4—straight line depreciation, 0 or other—user enters depreciation, or no depreciation considered)	NDEP
(31) the number of years in the planning period (1 to 20)	NYRS
(32) the number of years in the depreciation period (usually 5 years for most manufacturing related combustion equipment)	NYRD
(33) the investment tax credit afforded by investment in new assets (dollars at end of year 1)	ITCR
(34) the annual rate of increase or inflation in total working capital requirements	INRT
(35) total annual variable costs, excluding depreciation, during each year of the planning period (in dollars)	VCST
(36) total annual fixed costs, excluding depreciation, during each year of the planning period (in dollars)	FCST
(37) value of essential heat energy outputs in dollars per million Btu	HVAL
(38) value of surplus heat energy outputs in dollars per million Btu	SVAL
(39) average value of auxiliary or alternate fuel during each year of the planning period (in dollars per fuel sales unit)	PAXF
(40) average value of wood or bark fuel during each year of the planning period (dollars per fuel sales unit)	RVAL
(41) (optional) annual depreciation allowances for new assets during each year of the planning period, in dollars (required only if parameter 30 is not specified as 1, 2, 3, or 4, or if the user does not intend to have depreciation calculated on the basis of parameter 30)	DEPR

Note: Each of parameters 35 to 40 may be specified optionally as the first-year value and an estimated annual rate of increase. The computer will calculate the appropriate values for all other years in the planning period. All dollar amounts should be in terms of actual dollars (not indexed, "real," or constant value dollars).

title of each alternative, and the 41 items listed in tables 1 to 3. In most data processing facilities such data can be entered either by using keypunched data cards, or by writing the data on a tape or disk file. Data format is the same whether the computer reads a card deck, or a file. (It is important to follow the instructions provided here because if the correct format is not used the program may not function properly.) The instructions are given on a card by card basis, assuming the user will prepare a data card deck. The same format would apply if the user prepared a data file on disk or tape except that the data would be entered line by line on the data file instead of on cards.

Six types of cards must be used to prepare data in order to use the COMPARE program. The program variables and the format used on the six types of data cards are shown in figure 2. The six types of data cards are prepared as follows:

Card type 1.—The first card in the data deck (or first line in a data file) is always the type 1 card and only one to a deck. The only data on the type 1 card is the number of investment alternatives to be considered in the analysis. The program name of this entry is NALT. The user may specify an integer number from 2 to 10, which will correspond to the number of alternatives. The number is entered in the first two columns justified to the right (using FORMAT (I2)).

Card type 2.—The titles of the investment alternatives are entered separately on type 2 data cards with one card for each alternative. There will be from 2 to 10 type 2 data cards, depending on the number of alternatives specified (NALT). For example, if three alternatives are specified, there will be a separate title for each and one type 2 data card for each title. Each title can be up to 80 columns wide (using FORMAT (20 A4)). Furthermore, the sequence in which the titles are

entered determines the sequence in which remaining data are entered.

Card type 3.—Type 3 cards contain data on physical parameters of wood and bark fuel for each alternative. All of the parameters (1-13) described in table 1 are entered on type 3 data cards. The number of type 3 cards must be the same as the number of alternatives (NALT). Type 3 cards are prepared in the same sequence of alternatives as type 2 cards. The format for data entry is illustrated in figure 2.

If programed values are appropriate then the user does not have to enter the data. Four of the data items, as noted in table 1, have no programed values (AFMC, AWRU, RFS1 and RFS2, and NCAF). The user must always enter data for those items. However, any of the other items on type 3 data cards may be left blank, in which case the programed values shown in table 1 will be used.

Card type 4.—Data on the physical parameters of the energy system as outlined in table 2 are entered next on type 4 data cards. The number of type 4 cards is the same as the number of alternatives (NALT), and are prepared in the same sequence of alternatives as the type 2 cards. All of the data outlined in table 2 (parameters 14-22) are entered on the type 4 cards. The format for data entry is illustrated in figure 2. Values for the parameters EBTU, SBTU, and RAVL must always be entered by the user. Values for the other items need not be entered if programed values are appropriate (programed values are given in table 2).

Card type 5.—Type 5 data cards are used to enter part of the economic parameters outlined in table 3 (parameters 23-34). One type 5 data card is prepared for each of the alternatives (NALT), again using the same sequence of alternatives as the type 2 cards. This format is also illustrated in figure 2. Values for all economic parameters must be entered by the user because COMPARE has no programed values for economic data (none of the entries on the type 5 data cards should be blank, unless an entry of zero is intended).

Card type 6.—The last type of data card, type 6, is used for entering the remaining economic data (parameters 35-41 from table 3). Type 6 data cards differ from previous cards in that only one parameter for each alternative is entered on each type 6 card. Values for the following parameters are entered separately on type 6 cards: VCST, FCST, HVAL, SVAL, PAXF, RVAL, and optionally, DEPR. For each parameter, a value is required for each year in the planning period for each alternative. The number of years in the planning period (or economic life) of each alternative is the number specified for NYRS on the type 5 data card.

There are two options for entering data on type 6 cards. One option is to enter data values for each year of the planning period for each alternative. The second option is to enter only a first-year value followed by a decimal fraction which represents the annual rate of increase or decrease in the first-year value. Under the second option, the user does not have to provide estimates for each year of the planning period. Under that option, COMPARE will compute values for years following the first year by compounding the specified annual rate of increase or decrease over the entire planning period.

The sequence of data entry for type 6 data cards is as follows: First, the appropriate values are entered for the parameter VCST for the first alternative (using the sequence of alternatives established by type 2 cards). Only one card is required per alternative to enter values for VCST if the number of years in the planning period is 10 or less, or if a first-year value plus annual rate of increase is entered. Two cards are required if values for each year are entered and the number of years exceeds 10. After values for VCST are entered for the first alternative, values for VCST are entered for each of the remaining alternatives (again, following the sequence of alternatives established by type 2 cards), using the same instructions as for the first alternative. After VCST values have been entered for each of the alternatives, values for other parameters (FCST, HVAL, SVAL, PAXF, and RVAL in that sequence) are entered in the same way as VCST. Values for each alternative are entered before going to the next parameter. Again annual values for each year of the planning period may be entered; or optionally, just the first-year value (col. 1-8) plus the annual rate of increase as a decimal fraction (col. 9-16) may be entered.

COMPARE can calculate annual depreciation allowances based on user-specified investment in new assets, depreciation period, and selection of the appropriate schedule. The choice of depreciation schedule is made by the user in selecting the appropriate code for the variable NDEP for each alternative (1 for 1981 to 1984 ACRS schedule, 2 for 1985 ACRS schedule, 3 for 1986 and thereafter ACRS schedule, and 4 for straight line). Alternatively, the user can elect to enter annual depreciation allowances instead of having allowances calculated by the computer. That option is indicated by specifying some code value other than 1, 2, 3, or 4 for NDEP (e.g. by specifying 0 for example). If the user thus elects to enter annual depreciation data, the data are entered on type 6 cards, following the cards for RAVL, using the same sequence of alternatives. An allowance value must be entered for each year in the planning period. One card is required if the planning period is 10 years or less, two cards are required if the planning period is 11 to 20 years. No cards are required if codes 1, 2, 3, or 4 are specified for NDEP for a given alternative.

Sample Data

As illustrated with the sample data in figure 1, there is one type 1 data card (line 1), which specifies the number of alternatives ("3" in col. 1-2). There are three type 2 data cards which give the descriptive title of each alternative (lines 2-4); three type 3 data cards (lines

5-7); three type 4 data cards (lines 8-10 in fig. 1); and three type 5 data cards (lines 11-13 in fig. 1). Finally, there are 18 separate type 6 data cards (lines 14-31, in fig. 1).

Sample Program Output

When a COMPARE analysis is made with the sample data shown in figure 1, the results are the printed output shown in figure 3. The output consists of three parts. Part I of the printed output (the first two pages in fig. 3) has financial summaries for each of the three alternatives. The financial summaries show the investment parameters, fuel costs, and cash flows associated with each alternative. Annual net cash flows and present value of net cash flows are also provided.

A ranking of alternatives according to benefit cost ratios is found in part II of the printed output (one page). In the sample output (fig. 3), alternative 3 is ranked highest, with alternative 1 ranked lowest, according to benefit cost ratios. Generally, benefit cost ratios reveal the most economical of any two alternatives, provided that two sufficient assumptions can be made. The assumptions are that both alternatives will be replaced at the end of their economic lives by replacement projects which (1) have the same benefit cost ratio and carry the planning periods forward to an equal planning period for both alternatives, and (2) the replacement projects will have a benefit cost ratio that is between the ratios of the two alternatives evaluated over their current economic lives. The validity of benefit cost ratios as criteria and the two sufficient assumptions are discussed in the appendix.

Part III of the printed output (including tables 1-4 of the output) provides detailed information on the heat energy and fuel balance for each alternative. Table 1 of the output shows heat energy requirements and the proportions of energy requirements that are met by wood fuel and alternate or auxiliary fuel for each alternative. Table 1 also shows amounts of wood and alternate or auxiliary fuels that are needed annually to meet the energy requirements. Table 2 describes physical characteristics of the wood fuel and shows the amount of heat energy calculated as recoverable from the wood fuel (the recoverable heat energy estimate is used in COMPARE to determine the quantity of wood fuel required in each alternative based on heat output). Table 3 provides parameters related to the auxiliary or alternate (nonwood or bark) fuel. Table 4 shows selected parameters in terms of International System (SI) units.

Program Restrictions

COMPARE was developed as an analytical tool to aid in evaluating project feasibility, and as a research tool for economic evaluation of energy system alternatives. It is important for the user to recognize that parts I and III of the program output are not adequate to rank and compare investment alternatives. For valid comparison of alternatives, the user must refer to part II of the program output, which contains the benefit cost ratios.

COMPARE is quite versatile, being able to simulate a variety of different types of investment alternatives. Yet, the structure of analysis is somewhat restricted by the structure of COMPARE data input and program output. Restrictions could be removed by making the COMPARE program more complicated, but in its current form COMPARE balances sophisticated analysis and simplicity of data input. Some of the restrictions are discussed here.

One restriction is that COMPARE can simulate the use of only one type of wood or bark fuel and only one type of auxiliary or alternate fuel under each alternative. In order to simulate the use of more than one type of wood or alternate fuel it is necessary to enter data that simulate average parameter values. COMPARE could be reprogramed to handle data for more than one type of fuel in each alternative, but again that would add complexity.

Another restriction is that for each alternative COMPARE permits only one estimate of annual heat energy requirement, which remains the same for each year in the planning period. In some cases, it might be useful to assume that heat energy requirement changes during the planning period, but that sort of assumption cannot be handled by COMPARE in its current form. Again, the restriction could be removed by reprograming COMPARE to accept and analyze additional data input.

Another limitation is that COMPARE is designed for analysis of wood or bark energy systems that involve combustion and heat recovery from combustion gases, as opposed to energy systems that do not involve combustion. COMPARE contains an algorithm which calculates the recoverable heat energy from combustion of wood or bark fuels, and uses the recoverable heat estimate to determine heat output per unit of fuel and amount of fuel required. A user should understand that COMPARE is designed to calculate recoverable heat energy on the basis of physical parameters given in tables 1 and 2. The recoverable heat estimate is essentially the maximum amount of heat energy that will be recovered (e.g. in the form of steam) given the specified physical parameters. However, some circumstances could result in actual heat output being less than estimated recoverable heat energy. Those circumstances include situations where the furnace and boiler system are used very intermittently, or where heat energy is wasted after it is recovered. Such circumstances generally are assumed not to apply in any of the alternatives the user specifies.

Summary

COMPARE has considerable versatility and can simulate a variety of different types of investments in

wood energy systems. COMPARE allows considerable latitude in specification of the fuel type and associated physical parameters, parameters of the energy system, and financial and economic data. COMPARE was developed at the Forest Products Laboratory as an analytical tool for a variety of users; researchers, managers, engineers, and industrial consultants. It is intended that COMPARE will contribute to wise and efficient use of forest resources in the area of industrial energy systems.

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 3
FIRST ALTERNATIVE - RETAIN OLD BOILER SYSTEM FOR FIVE YEARS (GAS FIRED)
SECOND ALTERNATIVE - INSTALL NEW WOOD AND OIL FIRED SYSTEM
THIRD ALTERNATIVE - INSTALL NEW WOOD AND COAL FIRED SYSTEM
0.45 2000. O.D. TON                    8700. 2
0.45 2000. O.D. TON                    8700. 0
0.45 2000. O.D. TON                    8700. 1
 25230.            30000.                                         0.00
 25230.   100000.  30000.                                         0.90
 25230.   150000.  30000.                                         0.80
           20000.                           30000.    .20.35 0 5 5           .18
 1428000.  70000.   50000.     80000.      160000.    .20.35 110 5 500000.   .18
 1828000.  90000.   70000.     80000.      200000.    .20.35 110 5 650000.   .18
  35000.   0.15
  75000.   0.15
  90000.   0.15
  70000.   0.15
  90000.   0.15
 100000.   0.15
    6.0    0.20
    6.0    0.20
    6.0    0.20
    5.5   0.20
    5.5   0.20
    5.5   0.20
    5.25   0.25
   42.0    0.25
    65.0   0.15
     8.0   0.10
     8.0   0.10
     8.0   0.10
```

Figure 1.—Sample data input. (ML83 5039)

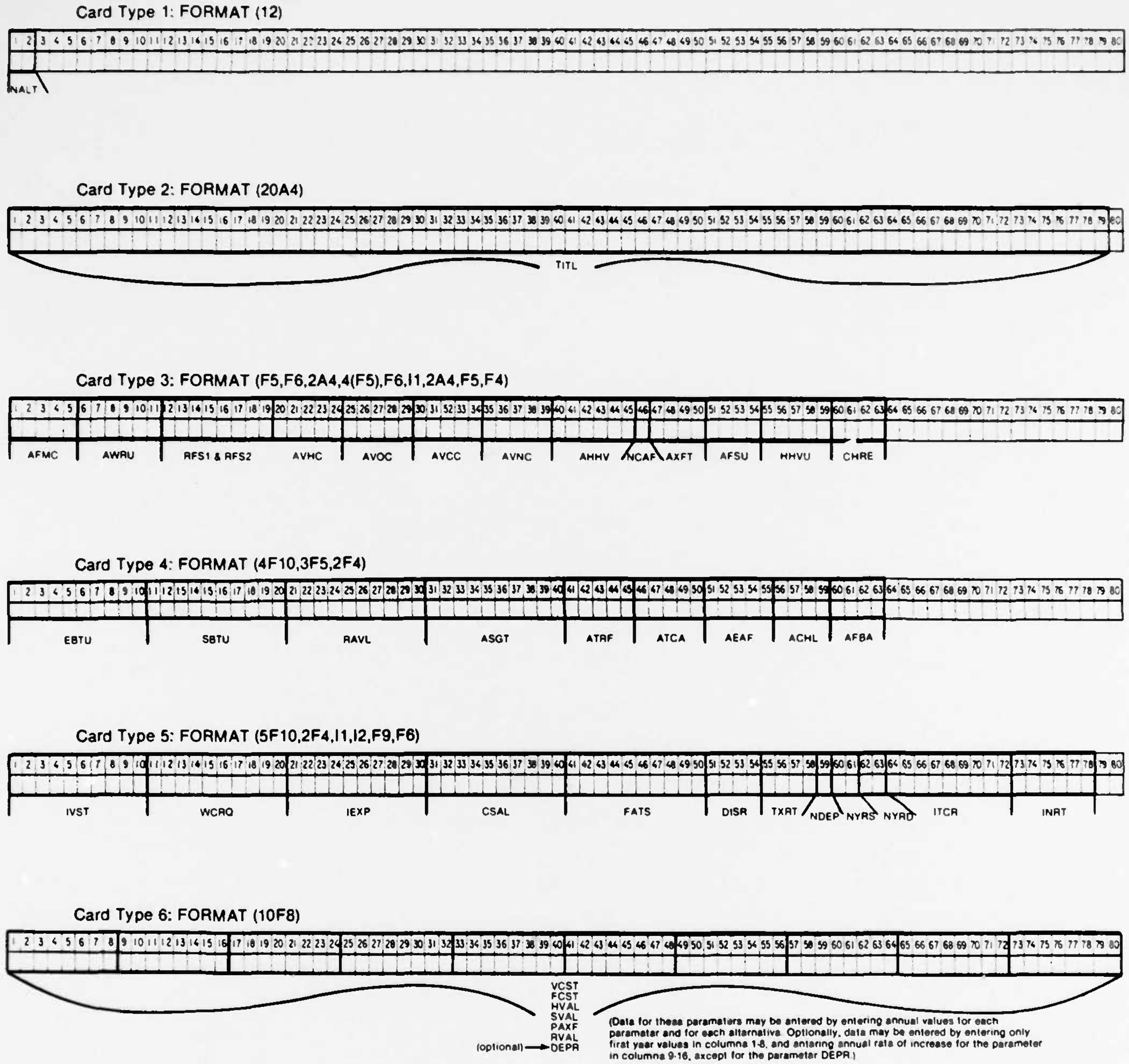

Figure 2.—Data card format and program parameters for card types 1-6. (ML83 5083)

```
PART I.  FINANCIAL SUMMARIES

FINANCIAL SUMMARY--ALTERNATIVE  1

FIRST ALTERNATIVE - RETAIN OLD BOILER SYSTEM FOR FIVE YEARS (GAS FIRED)

INVESTMENT PARAMETERS (YEAR 0):          ENDING NET SALVAGE (YEAR  5)$    30000.
 DEPRECIABLE ASSETS - - - $          0.  EFFECTIVE ANNUAL TAX RATE - - - -  .350
 NONDEPREC. EXPENSES- - - $          0.  HEAT ENERGY REQUIREMENTS AND OUTPUT:
 WORKING CAPITAL- - - - - $      20000.   ESSENTIAL REQ. - -     252230. MMBTU/YR.
 OLD FACILITY NET SALV. - $          0.   TOTAL OUTPUT - - -     252230. MMBTU/YR.

ANNUAL COSTS, DEPRECIATION AND AVERAGE ANNUAL
 COST PER MMBTU OF TOTAL ENERGY OUTPUTS

                 FUEL COSTS           OTHER VAR.    FIXED       DEPRE-     COST/
          WOOD-BARK         GAS         COSTS       COSTS       CIATION    MMBTU
              $              $            $           $            $         $
 YEAR  1          0.     1742378.      35000.      70000.           0.      7.32
 YEAR  2          0.     2177973.      40250.      80500.           0.      9.11
 YEAR  3          0.     2722466.      46287.      92575.           0.     11.34
 YEAR  4          0.     3403083.      53231.     106461.           0.     14.13
 YEAR  5          0.     4253853.      61215.     122430.           0.     17.59

BEFORE TAX NET EXPENSES, INVESTMENT TAX CREDIT, ADDITIONAL INVESTMENT (WORKING
 CAPITAL) AND AFTER TAX NET CASH FLOW INCLUDING SALVAGE (END OF YEAR VALUES):

                BEFORE TAX       TAX       ADDITIONAL      AFTER TAX
               NET EXPENSES     CREDIT     INVESTMENT     NET CASH FLOW
                    $             $            $               $
YEAR  0              0.                                     -20000.
YEAR  1        1847378.          0.          3600.        -1204396.
YEAR  2        2298723.                      4248.        -1498418.
YEAR  3        2861329.                      5013.        -1864876.
YEAR  4        3562774.                      5915.        -2321718.
YEAR  5        4437499.                      6980.        -2815599.

PRESENT VALUE (YEAR 0) OF AFTER TAX NET CASH FLOWS:

      $ -5394624.  AT 20.0 PERCENT ANNUAL DISCOUNT RATE


FINANCIAL SUMMARY--ALTERNATIVE  2

SECOND ALTERNATIVE - INSTALL NEW WOOD AND OIL FIRED SYSTEM

INVESTMENT PARAMETERS (YEAR 0):          ENDING NET SALVAGE (YEAR 10)$   160000.
 DEPRECIABLE ASSETS - - - $    1428000.  EFFECTIVE ANNUAL TAX RATE - - - -  .350
 NONDEPREC. EXPENSES- - - $      50000.  HEAT ENERGY REQUIREMENTS AND OUTPUT:
 WORKING CAPITAL- - - - - $      70000.   ESSENTIAL REQ. - -     252230. MMBTU/YR.
 OLD FACILITY NET SALV. - $      80000.   TOTAL OUTPUT - - -     352230. MMBTU/YR.

ANNUAL COSTS, DEPRECIATION AND AVERAGE ANNUAL
 COST PER MMBTU OF TOTAL ENERGY OUTPUTS

                 FUEL COSTS           OTHER VAR.    FIXED       DEPRE-     COST/
          WOOD-BARK         OIL         COSTS       COSTS       CIATION    MMBTU
              $              $            $           $            $         $
 YEAR  1     222344.      293525.      75000.      90000.      214200.      2.54
 YEAR  2     244578.      366906.      86250.     103500.      314160.      3.17
 YEAR  3     269036.      458633.      99187.     119025.      299880.      3.54
 YEAR  4     295940.      573291.     114066.     136879.      299880.      4.03
 YEAR  5     325534.      716614.     131175.     157411.      299880.      4.63
 YEAR  6     358087.      895767.     150852.     181022.           0.      4.50
 YEAR  7     393896.     1119709.     173480.     208175.           0.      5.38
 YEAR  8     433285.     1399636.     199501.     239402.           0.      6.45
 YEAR  9     476614.     1749545.     229427.     275312.           0.      7.75
 YEAR 10     524275.     2186932.     263841.     316609.           0.      9.35
```

Figure 3. — Sample program output.

BEFORE TAX NET EXPENSES, INVESTMENT TAX CREDIT, ADDITIONAL INVESTMENT (WORKING CAPITAL) AND AFTER TAX NET CASH FLOW INCLUDING SALVAGE (END OF YEAR VALUES):

	BEFORE TAX NET EXPENSES $	TAX CREDIT $	ADDITIONAL INVESTMENT $	AFTER TAX NET CASH FLOW $
YEAR 0	50000.			-1450500.
YEAR 1	895069.	500000.	12600.	119805.
YEAR 2	1115395.		14868.	-425714.
YEAR 3	1245761.		17544.	-527409.
YEAR 4	1420055.		20702.	-643658.
YEAR 5	1630613.		24429.	-784447.
YEAR 6	1585728.		28826.	-1059549.
YEAR 7	1895260.		34014.	-1265933.
YEAR 8	2271825.		40137.	-1516823.
YEAR 9	2730898.		47362.	-1822445.
YEAR 10	3291657.		55887.	-1669095.

PRESENT VALUE (YEAR 0) OF AFTER TAX NET CASH FLOWS:

$ -4260940. AT 20.0 PERCENT ANNUAL DISCOUNT RATE

FINANCIAL SUMMARY--ALTERNATIVE 3

THIRD ALTERNATIVE - INSTALL NEW WOOD AND COAL FIRED SYSTEM

INVESTMENT PARAMETERS (YEAR 0):		ENDING NET SALVAGE (YEAR 10)$	200000.
DEPRECIABLE ASSETS - - - $	1828000.	EFFECTIVE ANNUAL TAX RATE - - - -	.350
NONDEPREC. EXPENSES- - - $	70000.	HEAT ENERGY REQUIREMENTS AND OUTPUT:	
WORKING CAPITAL- - - - - $	90000.	ESSENTIAL REQ. - -	252230. MMBTU/YR.
OLD FACILITY NET SALV. - $	80000.	TOTAL OUTPUT - - -	402230. MMBTU/YR.

ANNUAL COSTS, DEPRECIATION AND AVERAGE ANNUAL COST PER MMBTU OF TOTAL ENERGY OUTPUTS

	FUEL COSTS		OTHER VAR.	FIXED	DEPRE-	COST/
	WOOD-BARK $	COAL $	COSTS $	COSTS $	CIATION $	MMBTU $
YEAR 1	225694.	325186.	90000.	100000.	274200.	2.52
YEAR 2	248264.	373964.	103500.	115000.	402160.	3.09
YEAR 3	273090.	430058.	119025.	132250.	383880.	3.33
YEAR 4	300399.	494567.	136879.	152087.	383880.	3.65
YEAR 5	330439.	568752.	157411.	174901.	383880.	4.02
YEAR 6	363483.	654065.	181022.	201136.	0.	3.48
YEAR 7	399831.	752175.	208175.	231306.	0.	3.96
YEAR 8	439814.	865001.	239402.	266002.	0.	4.50
YEAR 9	483796.	994751.	275312.	305902.	0.	5.12
YEAR 10	532176.	1143964.	316609.	351788.	0.	5.83

BEFORE TAX NET EXPENSES, INVESTMENT TAX CREDIT, ADDITIONAL INVESTMENT (WORKING CAPITAL) AND AFTER TAX NET CASH FLOW INCLUDING SALVAGE (END OF YEAR VALUES):

	BEFORE TAX NET EXPENSES $	TAX CREDIT $	ADDITIONAL INVESTMENT $	AFTER TAX NET CASH FLOW $
YEAR 0	70000.			-1883500.
YEAR 1	1015080.	650000.	16200.	248198.
YEAR 2	1242888.		19116.	-424833.
YEAR 3	1338304.		22557.	-508574.
YEAR 4	1467813.		26617.	-596815.
YEAR 5	1615383.		31408.	-697527.
YEAR 6	1399706.		37062.	-946871.
YEAR 7	1591488.		43733.	-1078200.
YEAR 8	1810219.		51605.	-1228247.
YEAR 9	2059761.		60894.	-1399738.
YEAR 10	2344536.		71854.	-924757.

PRESENT VALUE (YEAR 0) OF AFTER TAX NET CASH FLOWS:

$ -4158436. AT 20.0 PERCENT ANNUAL DISCOUNT RATE

Figure 3.—Sample program output (continued).

PART II. BENEFIT COST RATIOS FOR ALL ALTERNATIVES

FIRST YEAR HEAT ENERGY VALUES (USER SPECIFIED) AND DISCOUNTED PRESENT VALUE OF HEAT ENERGY FOR EACH ALTERNATIVE:

	HEAT ENERGY VALUE ($/MMBTU) ESSENTIAL ENERGY	SURPLUS ENERGY	PRESENT VALUE OF HEAT ENERGY (BASED ON ESSENTIAL)	(INCLUDING SURPLUS)	DISCOUNT RATE (PCT.)
ALT 1	6.00	5.50	6305750.	6305750.	20.0
ALT 2	6.00	5.50	12611499.	17194833.	20.0
ALT 3	6.00	5.50	12611499.	19486499.	20.0

RANKING OF ALTERNATIVES BY HIGHEST BENEFIT COST RATIO (RATIO OF P.V. OF HEAT ENERGY OUTPUT TO P.V. OF AFTER TAX NET CASH FLOW) BASED ON ESSENTIAL HEAT ENERGY REQUIREMENTS:

	B/C RATIO	REQUIRED NET INVESTMENT
ALT 3	3.03	1908000.0
ALT 2	2.96	1468000.0
ALT 1	1.17	20000.0

RANKING OF ALTERNATIVES BY HIGHEST BENEFIT COST RATIO BASED ON TOTAL HEAT ENERGY OUTPUT (INCLUDING SURPLUS):

	B/C RATIO	REQUIRED NET INVESTMENT
ALT 3	4.69	1908000.0
ALT 2	4.04	1468000.0
ALT 1	1.17	20000.0

PART III. DESCRIPTION OF ENERGY BALANCE AND FUEL PARAMETERS FOR EACH ALTERNATIVE (TABLES 1 TO 4)

TABLE 1.--HEAT ENERGY BALANCE AND FUEL REQUIREMENTS (ANNUAL BASIS)

	ESSENTIAL ENERGY REQUIREMENTS (MMBTU)	SURPLUS ENERGY REQUIREMENTS (MMBTU)	TOTAL ENERGY OUTPUT (MMBTU)
ALT 1	252230.	0.	252230.
ALT 2	252230.	100000.	352230.
ALT 3	252230.	150000.	402230.

	ENERGY SUPPLIED BY WOOD-BARK FUEL (MMBTU)	(PCT. OF TOTAL)	ENERGY SUPPLIED BY OTHER OR AUXILIARY FUEL (MMBTU)	(PCT. OF TOTAL)
ALT 1	0.	.0	252230.	100.0
ALT 2	317007.	90.0	35223.	10.0
ALT 3	321784.	80.0	80446.	20.0

	QUANTITY OF WOOD-BARK AVAILABLE	WOOD-BARK FUEL REQUIREMENTS	OTHER FUEL REQUIREMENTS
ALT 1	30000. O.D. TON	0. O.D. TON	331882. MCF (GAS)
ALT 2	30000. O.D. TON	27793. O.D. TON	6989. BBL. (OIL)
ALT 3	30000. O.D. TON	28212. O.D. TON	5003. TON (COAL)

Figure 3.—Sample program output (continued).

TABLE 2.--WOOD-BARK FUEL PARAMETERS AND ESTIMATED HEAT RECOVERY

	OVENDRY WT (LBS) PER SALES UNIT	MOISTURE CONT. (DRY WT BASIS)	WET WT (LBS) PER SALES UNIT	MOISTURE CONT. (WET WT BASIS)
ALT 1	2000./O.D. TON	.82	3636./O.D. TON	.45
ALT 2	2000./O.D. TON	.82	3636./O.D. TON	.45
ALT 3	2000./O.D. TON	.82	3636./O.D. TON	.45

	HIGHER HEAT VALUE (BTU/DRY LB)	- - - - - ESTIMATED HEAT ENERGY RECOVERY (BTU/DRY LB)	(BTU/WET LB)	- - - - - (MMBTU/SALES UNIT)
ALT 1	8700.	5703.	3137.	11.406/O.D. TON
ALT 2	8700.	5703.	3137.	11.406/O.D. TON
ALT 3	8700.	5703.	3137.	11.406/O.D. TON

TABLE 3.--OTHER OR AUXILIARY FUEL PARAMETERS

	TYPE OF FUEL	HIGHER HEAT VALUE (MMBTU)	ESTIMATED HEAT RECOVERY (MMBTU)
ALT 1	GAS	1.00/ MCF	.76/ MCF
ALT 2	OIL	6.30/BBL.	5.04/BBL.
ALT 3	COAL	24.00/ TON	16.08/ TON

TABLE 4.--INTERNATIONAL SYSTEM (SI) UNIT RECOVERABLE HEAT ENERGY ESTIMATES

	- - - - - - ENERGY IN WOOD-BARK FUEL (KJOULE/KG DRY BASIS)	(KJOULE/KG WET BASIS)	- - - - - - - - (BILLION JOULE PER SALES UNIT)	-OTHER FUEL - - (BILLION JOULE PER SALES UNIT)
ALT 1	13275.	7301.	26.6/O.D. TON	1.8/ MCF
ALT 2	13275.	7301.	26.6/O.D. TON	11.7/BBL.
ALT 3	13275.	7301.	26.6/O.D. TON	37.4/ TON

Figure 3.—Sample program output (continued).

Appendix

Benefit Cost Ratios in COMPARE

A major purpose of COMPARE is to provide an objective comparison of different investment alternatives in wood or bark energy systems. However, in the case of investment alternatives in wood and bark energy systems it is likely that the economic lives, initial investment requirements, and the discount rates will all be different among different alternatives. It is necessary therefore to adopt an economic criterion which will be valid for comparison despite the varied nature of the alternatives.

Consider discounted benefit cost ratios which are generally valid criteria even if the discount rates and investment requirements are different among alternatives. Discounted benefit cost ratios are derived on the basis of discount rates and therefore take into account any difference in discount rates. If the investment requirements are different, the opportunity cost of higher capital requirements for one alternative can be taken into account by simply increasing the discount rate for the higher investment alternative. The difference in discount rate will again be reflected in the benefit cost ratio. Hence, the only problem in regard to use of benefit cost ratios as criteria is that of unequal economic lives.

As will be shown here, the discounted benefit cost ratio will serve as a valid criterion for comparison of any two investment alternatives provided that two sufficient assumptions can be made. The sufficient assumptions are that (1) both alternatives are replaced by replacement projects which both have the same benefit cost ratio and which carry the planning period forward to an equal overall planning period for both alternatives, and (2) the replacement project's benefit cost ratio is numerically in the same range as (e.g. between) the benefit cost ratios of the two investment alternatives over their current economic lives. Under these reasonable assumptions, the most economical of two current investment alternatives will always be the one with the highest benefit cost ratio, calculated over the economic life of each alternative, even if the alternatives have different economic lives.

Consider any two investment alternatives. The two alternatives may have different economic lives, different initial investment requirements, and different discount rates. Economic common sense implies that the two alternatives cannot be compared directly unless they represent the same interval in time, the same planning period. For example, suppose there are two mutually exclusive investment alternatives which involve installation of two different types of boiler systems. One system has an economic or service life which is 30 percent longer than the other. Just the benefits and costs of the two alternatives alone will not show which alternative is most economical because the cost of replacing the shorter lived alternative must be considered. Replacement projects have benefits and costs which must be considered, and may have different economic lives. In fact, it is necessary to choose a planning period which includes the economic lives of current investments plus the lives of selected replacement project(s) for both alternatives, such that the overall planning periods are equal for both alternatives. (Note that if both current investment alternatives have the same economic life, replacement projects need not be considered.)

It should be noted at this point that the standard approach to the problem of unequal economic lives, which is recommended in many texts, is to try to estimate the cash flows of replacement projects such that cash flows will be obtained for both alternatives over an equal planning period. However, anyone who is familiar with cost estimation knows that estimation of costs and numerical benefits for a replacement project is a very imprecise task especially if the project is scheduled for many years from now. It is often difficult just to obtain reliable estimates for well understood current investment alternatives, let alone tentative future replacement projects. In developing COMPARE the obvious question was asked—"Is there some way to avoid the difficult task of having to estimate benefits and costs for future replacement projects, and still be able to use the simple benefit cost ratios of current alternatives as a valid criteria for comparison?" The answer was "yes" provided that two sufficient assumptions (introduced previously) can be made. The rationale for why those assumptions permit use of benefit cost ratios in directly comparing two Investment alternatives is presented as follows.

Let the benefit cost ratios of two investment alternatives be denoted as B1/C1 and B2/C2 respectively. In both cases, the benefit cost ratios are the ratio of discounted benefit values to discounted costs (or after tax net cash flows based on costs as in COMPARE). Thus,

$$\frac{\text{(Present value of benefits for first alternative)}}{\text{(Present value of costs for first alternative)}} = \frac{B1}{C1}$$

$$\frac{\text{(Present value of benefits for second alternative)}}{\text{(Present value of costs for second alternative)}} = \frac{B2}{C2}$$

In considering future replacement projects it is necessary to establish a basic fact about benefit cost ratios. The fact is that if associated benefits and costs are further discounted to an earlier point in time, the numerical value of the benefit cost ratio will remain the same. That fact is true regardless of the discount rate or length of discount period. For example, consider some future replacement project. The replacement project has benefit values and costs which can be discounted to the beginning of the economic life of the project (some future point in time). The discounted benefits and costs can then be expressed as a benefit cost ratio for the replacement project. Now suppose that the same benefit values and costs are discounted to the present point in time, and are then expressed as a present benefit cost ratio. The fact is that the present benefit cost ratio will be exactly the same as the benefit cost ratio derived for the future point in time.

Denote the benefit cost ratio of the future replacement projects as Br1/Cr1 for the first alternative and Br2/Cr2 for the second alternative. A replacement project benefit cost ratio is the ratio of discounted benefit values (Br) to discounted costs (Cr) for the replacement project. Benefits and costs are discounted to the future point in time at which the replacement project begins and at which the economic life of the current investment ends. That point in time will be denoted as year n for the first alternative and year m for the second alternative. Thus,

For 1st Alt.: $$\frac{Br1(n)}{Cr1(n)} = \frac{\text{(Year n value of benefits for the replacement project)}}{\text{(Year n value of costs for the replacement project)}}$$

For 2nd Alt.: $$\frac{Br2(m)}{Cr2(m)} = \frac{\text{(Year m value of benefits for the replacement project)}}{\text{(Year m value of costs for the replacement project)}}$$

The first sufficient assumption is that future replacement projects for both alternatives will have the same benefit cost ratio. The assumption implies that Br1(n)/Cr1(n) = Br2(m)/Cr2(m). It can now be observed that if a replacement project's benefits and costs are discounted to prevent values and are then expressed as a ratio, the ratio will equal the original benefit cost ratio for the replacement project. In other words, if Br1(p) is the present value of benefits and Cr1(p) is the present value of costs for the replacement project under the first alternative, then the following ratios are equal:

$$\frac{Br1(p)}{Cr1(p)} = \frac{Br1(n)/(1 + i)^n}{Cr1(n)/(1 + i)^n} = \frac{Br1(n)}{Cr1(n)}$$

(where i is the discount rate).

Likewise, if Br2(p) equals the present value of benefits and Cr2(p) equals the present value of costs for the replacement project under the second alternative, the following ratios are also equal:

$$\frac{Br2(p)}{Cr2(p)} = \frac{Br2(m)/(1 + i)^m}{Cr2(m)/(1 + i)^m} = \frac{Br2(m)}{Cr2(m)}$$

It is true then that the following equality holds:

$$\frac{Br1(p)}{Cr1(p)} = \frac{Br2(p)}{Cr2(p)}$$

Because, by assumption, $\frac{Br1(n)}{Cr1(n)} = \frac{Br2(m)}{Cr2(m)}$

It is finally necessary to recognize another basic fact concerning mathematical ratios and combinations of ratios. Suppose there are four numerical values, B1, C1, B2, and C2 (the values are analogous to the present values of benefits and costs of two current investment projects or alternatives, which may have different economic lives). Suppose arbitrarily that the ratios of the values are different so that one ratio is greater than the other as follows:

$$\frac{B1}{C1} > \frac{B2}{C2}$$

(If the ratios are benefit cost ratios, it would appear that the first alternative is more economical because it has a higher benefit cost ratio. However, as discussed earlier, replacement project benefits and costs must also be considered if the two current alternatives have different economic lives.)

Furthermore, suppose there are four other numerical values, Br1(p), Cr1(p), Br2(p), and Cr2(p). (Those values correspond to the present values of benefits and costs of replacement projects under the two alternatives. The replacement projects in both cases carry the alternatives forward to a planning period which is the same for both alternatives.) Now we can assume that those values satisfy the following relationship:

$$\frac{Br1(p)}{Cr1(p)} = \frac{Br2(p)}{Cr2(p)}$$

(This corresponds to the first sufficient assumption that benefit cost ratios are the same for replacement projects under both alternatives.) Also assume that the following relationship holds:

$$\frac{B1}{C1} > \frac{Br1(p)}{Cr1(p)} = \frac{Br2(p)}{Cr2(p)} > \frac{B2}{C2}$$

(This relationship corresponds to the second sufficient assumption that the benefit cost ratios of replacement projects are numerically between the benefit cost ratios of the two current investment alternatives.)

Then it is a fact that so long as the previous assumptions hold, the following result always holds regardless of the values represented by the eight terms:

$$\frac{B1 + Br1(p)}{C1 + Cr1(p)} > \frac{B2 + Br2(p)}{C2 + Cr2(p)}$$

(The last result says simply that the benefit cost ratio of the first alternative is higher than the benefit cost ratio of the second alternative, even when replacement projects and an equal planning period for both alternatives are taken into account.)

A proof of the last result is given as follows:

Suppose $\frac{B1}{C1} > \frac{B2}{C2}$ (arbitrary assumption),

$\frac{Br1(p)}{Cr1(p)} = \frac{Br2(p)}{Cr2(p)}$ (first sufficient assumption),

and,

$$\frac{B1}{C1} > \frac{Br1(p)}{Cr1(p)} = \frac{Br2(p)}{Cr2(p)} > \frac{B2}{C2}$$

(second sufficient assumption).

Then,

$$\frac{B1}{C1} > \frac{B1 + Br1(p)}{C1 + Cr1(p)} > \frac{Br1(p)}{Cr1(p)}$$

and,

$$\frac{Br2(p)}{Cr2(p)} > \frac{B2 + Br2(p)}{C2 + Cr2(p)} > \frac{B2}{C2}$$

therefore,

$$\frac{B1 + Br1(p)}{C1 + Cr1(p)} > \frac{B2 + Br2(p)}{C2 + Cr2(p)}$$

Thus, under the two sufficient assumptions, the following result will be true:

$$\frac{B1}{C1} > \frac{B2}{C2} \text{ implies } \frac{B1 + Br1(p)}{C1 + Cr1(p)} > \frac{B2 + Br2(p)}{C2 + Cr2(p)}$$

Likewise, under reverse assumptions, the opposite will also be true:

$$\frac{B2}{C2} > \frac{B1}{C1} \text{ implies } \frac{B2 + Br2(p)}{C2 + Cr2(p)} > \frac{B1 + Br1(p)}{C1 + Cr1(p)}$$

Therefore, under the two sufficient assumptions regardless of the economic lives of two current investment alternatives, the one with the highest benefit cost ratio will be the most economical even when replacement projects and equalized planning periods are considered. Under the two sufficient assumptions, it is not necessary to consider replacement projects or equalization of planning periods for either alternative, provided that discounted benefit cost ratios are used to compare the two alternatives.

Finally, the appropriateness of the two sufficient assumptions can be addressed. In regard to the first assumption of equal benefit cost ratios for replacement projects over equal planning periods, it may be helpful to think of the replacement projects for both alternatives as extending over an infinite planning period. As the planning period goes to infinity, it becomes relatively equal for both alternatives. Also, if the same sort of replacement project will be undertaken in both alternatives, it follows that both replacement projects have the same benefit cost ratio. The second sufficient assumption that the replacement project benefit cost ratio will be between the benefit cost ratios of the two current alternatives is equivalent to saying that the future replacement project will be neither less economical than the least economical current alternative, nor more economical than the most economical current alternative. Both assumptions must be recognized as merely sufficient, not necessary assumptions. In other words, benefit cost ratios may still be valid criteria for comparing two alternatives in certain cases where the assumptions are not met.

In summary, it is valid to compare any two current investment alternatives by comparing their benefit cost ratios even if the two alternatives have different economic lives (e.g. the most economical alternative is the one with the highest benefit cost ratio), provided the following two sufficient assumptions can be made: (1) the replacement projects which carry the planning periods forward to an equal planning period will have the same benefit cost ratio in both cases, and (2) the replacement project benefit cost ratio will be numerically in the range (e.g. between) the benefit cost ratios of the two current investment alternatives. Under those assumptions, the investment with the highest current benefit cost ratio is indeed the alternative which provides the greatest discounted return per unit of discounted cost.

Listing of the COMPARE Program

Subroutine DEP

```
      SUBROUTINE DEP                                                    DEP00010
C *** THIS SUBROUTINE CALCULATES DEPRECIATION ALLOWANCES FOR ECONOMIC    DEP00020
C *** ALTERNATIVES (J), UNLESS THE USER HAS SPECIFIED ANNUAL ALLOWANCES.DEP00030
C *** THE USER MAY ALWAYS ENTER DEPRECIATION ALLOWANCES AS DATA,        DEP00040
C *** INSTEAD OF HAVING THE SCHEDULE CALCULATED BY THIS SUBROUTINE.     DEP00050
C *** DATA REQUIREMENTS INCLUDE: USER CODE SPECIFICATION OF THE TYPE OF DEP00040
C *** SCHEDULE (CODE VARIABLE, NDEP(J)), 1= U.S. INTERNAL REVENUE       DEP00050
C *** SERVICE (IRS) SCHEDULES FOR NEW PROPERTY PUT IN SERVICE FROM      DEP00060
C *** 1981 TO 1984, 2=IRS SCHEDULES FOR NEW PROPERTY PUT IN SERVICE     DEP00070
C *** IN 1985, 3=IRS SCHEDULES FOR NEW PROPERTY PUT IN SERVICE IN 1986  DEP00080
C *** AND THEREAFTER, 4=STRAIGHT-LINE DEPRECIATION.  ALL SCHEDULES      DEP00090
C *** CORRESPOND TO THE MANDATORY (1981) ACCELERATED COST RECOVERY      DEP00100
C *** SYSTEM GUIDELINES.  ADDITIONAL DATA REQUIRED ARE THE NUMBER OF    DEP00110
C *** ALTERNATIVES (NALT), INITIAL ASSET VALUE (IVST(J)), AND           DEP00120
C *** DEPRECIATION PERIOD (NYRD(J)).  DEPRECIATION PERIOD MUST EQUAL    DEP00130
C *** 3, 5, 10, OR 15 YEARS UNDER OPTIONS 1, 2, OR 3, OTHERWISE         DEP00140
C *** STRAIGHT-LINE DEPRECIATION WILL BE CALCULATED.                    DEP00150
C *** ACCORDING TO STATUTORY GUIDELINES, SALVAGE VALUE IS               DEP00160
C *** DISREGARDED.  THE USER WILL SELECT THE APPROPRIATE SCHEDULE       DEP00170
C *** DEPENDING ON WHEN THE INVESTEMENT IS PUT IN PLACE, AND WILL ALSO  DEP00180
C *** SELECT THE APPROPRIATE DEPRECIATION PERIOD ACCORDING TO ACRS      DEP00190
C *** GUIDELINES; (GENERALLY 5 YEARS IS APPROPRIATE FOR NEW             DEP00200
C *** MANUFACTURING EQUIPMENT UNDER CURRENT GUIDELINES).  INITIAL       DEP00210
C *** DEPRECIATION BASIS EQUALS INITIAL ASSET VALUE (IVST).  IF THE     DEP00220
C *** USER DOES NOT ENTER OPTIONS 1, 2, 3, OR 4, (IF CODE VARIABLE      DEP00230
C *** NDEP IS SPECIFIED AS 0 OR SOME OTHER NUMBER), THEN IT IS ASSUMED  DEP00240
C *** AND REQUIRED THAT THE USER ENTER DEPRECIATION ALLOWANCES AS DATA  DEP00250
C *** (SEE DATA INPUT INSTRUCTIONS IN DOCUMENTATION REPORT).            DEP00260
C                                                                       DEP00270
      COMMON/ALL/AEMC(10),AHHV(10),AWRU(10),AXFT(10),                   DEP00280
     +  BTUR(10),DISP(10),FBTU(10),FATS(10),                            DEP00290
     +  HHVU(10),HRAF(10),HRRF(10),IVST(10),NYRS(10),PVAT(10),PCT(10),  DEP00300
     +  RAVL(10),RECY(10),TAUX(10),TRES(10),DEPR(10,20),                DEP00310
     +  NALT,NOR1,NYRD(10)                                              DEP00320
      COMMON/DEP1/B(21),D(10),NDEP(10),                                 DEP00330
      REAL IVST                                                         DEP00340
C                                                                       DEP00350
      DO 10 J=1,NALT                                                    DEP00360
      IF(NDEP(J).LT.1.OR.NDEP(J).GT.4) GO TO 10                         DEP00370
      NK=NYRD(J)                                                        DEP00380
      NYR=NYRS(J)                                                       DEP00390
      B(1) = IVST(J)                                                    DEP00400
      DO  100 N=1,NYR                                                   DEP00410
      DEPR(J,N)=0.0                                                     DEP00420
  100 CONTINUE                                                          DEP00430
C *** CALCULATE  (ACRS) DEPRECIATION                                    DEP00440
      IF(NDEP(J).EQ.1) GO TO 1                                          DEP00450
      IF(NDEP(J).EQ.2) GO TO 2                                          DEP00460
      IF(NDEP(J).EQ.3) GO TO 3                                          DEP00470
      IF(NDEP(J).EQ.4) GO TO 4                                          DEP00480
    1 CONTINUE                                                          DEP00490
      IF (NK.EQ.3) GO TO 11                                             DEP00500
      IF (NK.EQ.5) GO TO 12                                             DEP00510
      IF (NK.EQ.10) GO TO 13                                            DEP00520
      IF (NK.EQ.15) GO TO 14                                            DEP00530
      GO TO 4                                                           DEP00540
   11 CONTINUE                                                          DEP00550
      DEPR (J,1) = 0.25 * B(1)                                          DEP00560
      DEPR (J,2) = 0.38 * B(1)                                          DEP00570
      DEPR (J,3) = 0.37 * B(1)                                          DEP00580
      GO TO 10                                                          DEP00590
   12 CONTINUE                                                          DEP00600
      DEPR (J,1) = 0.15 * B(1)                                          DEP00610
      DEPR (J,2) = 0.22 * B(1)                                          DEP00620
      DEPR (J,3) = 0.21 * B(1)                                          DEP00630
      DEPR (J,4) = 0.21 * B(1)                                          DEP00640
      DEPR (J,5) = 0.21 * B(1)                                          DEP00650
      GO TO 10                                                          DEP00660
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   13 CONTINUE                                                          DEP00670
      DEPR (J,1) = 0.08 * B(1)                                          DEP00680
      DEPR (J,2) = 0.14 * B(1)                                          DEP00690
      DEPR (J,3) = 0.12 * B(1)                                          DEP00700
      DEPR (J,4) = 0.10 * B(1)                                          DEP00710
      DEPR (J,5) = 0.10 * B(1)                                          DEP00720
      DEPR (J,6) = 0.10 * B(1)                                          DEP00730
      DEPR (J,7) = 0.09 * B(1)                                          DEP00740
      DEPR (J,8) = 0.09 * B(1)                                          DEP00750
      DEPR (J,9) = 0.09 * B(1)                                          DEP00760
      DEPR (J,10) = 0.09 * B(1)                                         DEP00770
      GO TO 10                                                          DEP00780
   14 CONTINUE                                                          DEP00790
      DEPR (J,1) = 0.05 * B(1)                                          DEP00800
      DEPR (J,2) = 0.10 * B(1)                                          DEP00810
      DEPR (J,3) = 0.09 * B(1)                                          DEP00820
      DEPR (J,4) = 0.08 * B(1)                                          DEP00830
      DEPR (J,5) = 0.07 * B(1)                                          DEP00840
      DEPR (J,6) = 0.07 * B(1)                                          DEP00850
      DEPR (J,7) = 0.06 * B(1)                                          DEP00860
      DEPR (J,8) = 0.06 * B(1)                                          DEP00870
      DEPR (J,9) = 0.06 * B(1)                                          DEP00880
      DEPR (J,10) = 0.06 * B(1)                                         DEP00890
      DEPR (J,11) = 0.06 * B(1)                                         DEP00900
      DEPR (J,12) = 0.06 * B(1)                                         DEP00910
      DEPR (J,13) = 0.06 * B(1)                                         DEP00920
      DEPR (J,14) = 0.06 * B(1)                                         DEP00930
      DEPR (J,15) = 0.06 * B(1)                                         DEP00940
      GO TO 10                                                          DEP00950
    2 CONTINUE                                                          DEP00960
      IF (NK.EQ.3) GO TO 21                                             DEP00970
      IF (NK.EQ.5) GO TO 22                                             DEP00980
      IF (NK.EQ.10) GO TO 23                                            DEP00990
      IF (NK.EQ.15) GO TO 24                                            DEP01000
      GO TO 4                                                           DEP01010
   21 CONTINUE                                                          DEP01020
      DEPR (J,1) = 0.29 * B(1)                                          DEP01030
      DEPR (J,2) = 0.47 * B(1)                                          DEP01040
      DEPR (J,3) = 0.24 * B(1)                                          DEP01050
      GO TO 10                                                          DEP01060
   22 CONTINUE                                                          DEP01070
      DEPR (J,1) = 0.18 * B(1)                                          DEP01080
      DEPR (J,2) = 0.33 * B(1)                                          DEP01090
      DEPR (J,3) = 0.25 * B(1)                                          DEP01100
      DEPR (J,4) = 0.16 * B(1)                                          DEP01110
      DEPR (J,5) = 0.08 * B(1)                                          DEP01120
      GO TO 10                                                          DEP01130
   23 CONTINUE                                                          DEP01140
      DEPR (J,1) = 0.09 * B(1)                                          DEP01150
      DEPR (J,2) = 0.19 * B(1)                                          DEP01160
      DEPR (J,3) = 0.16 * B(1)                                          DEP01170
      DEPR (J,4) = 0.14 * B(1)                                          DEP01180
      DEPR (J,5) = 0.12 * B(1)                                          DEP01190
      DEPR (J,6) = 0.10 * B(1)                                          DEP01200
      DEPR (J,7) = 0.08 * B(1)                                          DEP01210
      DEPR (J,8) = 0.06 * B(1)                                          DEP01220
      DEPR (J,9) = 0.04 * B(1)                                          DEP01230
      DEPR (J,10) = 0.02 * B(1)                                         DEP01240
      GO TO 10                                                          DEP01250
   24 CONTINUE                                                          DEP01260
      DEPR (J,1) = 0.06 * B(1)                                          DEP01270
      DEPR (J,2) = 0.12 * B(1)                                          DEP01280
      DEPR (J,3) = 0.12 * B(1)                                          DEP01290
      DEPR (J,4) = 0.11 * B(1)                                          DEP01300
      DEPR (J,5) = 0.10 * B(1)                                          DEP01310
      DEPR (J,6) = 0.09 * B(1)                                          DEP01320
      DEPR (J,7) = 0.08 * B(1)                                          DEP01330
      DEPR (J,8) = 0.07 * B(1)                                          DEP01340
      DEPR (J,9) = 0.06 * B(1)                                          DEP01350
      DEPR (J,10) = 0.05 * B(1)                                         DEP01360
      DEPR (J,11) = 0.04 * B(1)                                         DEP01370
      DEPR (J,12) = 0.04 * B(1)                                         DEP01380
      DEPR (J,13) = 0.03 * B(1)                                         DEP01390
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      DEPR (J,14) = 0.02 * B(1)                                         DEP01400
      DEPR (J,15) = 0.01 * B(1)                                         DEP01410
      GO TO 10                                                          DEP01420
    3 CONTINUE                                                          DEP01430
      IF (NK.EQ.3) GO TO 31                                             DEP01440
      IF (NK.EQ.5) GO TO 32                                             DEP01450
      IF (NK.EQ.10) GO TO 33                                            DEP01460
      IF (NK.EQ.15) GO TO 34                                            DEP01470
      GO TO 4                                                           DEP01480
   31 CONTINUE                                                          DEP01490
      DEPR (J,1) = 0.33 * B(1)                                          DEP01500
      DEPR (J,2) = 0.45 * B(1)                                          DEP01510
      DEPR (J,3) = 0.22 * B(1)                                          DEP01520
      GO TO 10                                                          DEP01530
   32 CONTINUE                                                          DEP01540
      DEPR (J,1) = 0.20 * B(1)                                          DEP01550
      DEPR (J,2) = 0.32 * B(1)                                          DEP01560
      DEPR (J,3) = 0.24 * B(1)                                          DEP01570
      DEPR (J,4) = 0.16 * B(1)                                          DEP01580
      DEPR (J,5) = 0.08 * B(1)                                          DEP01590
      GO TO 10                                                          DEP01600
   33 CONTINUE                                                          DEP01610
      DEPR (J,1) = 0.10 * B(1)                                          DEP01620
      DEPR (J,2) = 0.18 * B(1)                                          DEP01630
      DEPR (J,3) = 0.16 * B(1)                                          DEP01640
      DEPR (J,4) = 0.14 * B(1)                                          DEP01650
      DEPR (J,5) = 0.12 * B(1)                                          DEP01660
      DEPR (J,6) = 0.10 * B(1)                                          DEP01670
      DEPR (J,7) = 0.08 * B(1)                                          DEP01680
      DEPR (J,8) = 0.06 * B(1)                                          DEP01690
      DEPR (J,9) = 0.04 * B(1)                                          DEP01700
      DEPR (J,10) = 0.02 * B(1)                                         DEP01710
      GO TO 10                                                          DEP01720
   34 CONTINUE                                                          DEP01730
      DEPR (J,1) = 0.07 * B(1)                                          DEP01740
      DEPR (J,2) = 0.12 * B(1)                                          DEP01750
      DEPR (J,3) = 0.12 * B(1)                                          DEP01760
      DEPR (J,4) = 0.11 * B(1)                                          DEP01770
      DEPR (J,5) = 0.10 * B(1)                                          DEP01780
      DEPR (J,6) = 0.09 * B(1)                                          DEP01790
      DEPR (J,7) = 0.08 * B(1)                                          DEP01800
      DEPR (J,8) = 0.07 * B(1)                                          DEP01810
      DEPR (J,9) = 0.06 * B(1)                                          DEP01820
      DEPR (J,10) = 0.05 * B(1)                                         DEP01830
      DEPR (J,11) = 0.04 * B(1)                                         DEP01840
      DEPR (J,12) = 0.03 * B(1)                                         DEP01850
      DEPR (J,13) = 0.03 * B(1)                                         DEP01860
      DEPR (J,14) = 0.02 * B(1)                                         DEP01870
      DEPR (J,15) = 0.01 * B(1)                                         DEP01880
      GO TO 10                                                          DEP01890
    4 CONTINUE                                                          DEP01900
      DO 41 N = 1,NK                                                    DEP01910
      IF(NYRD(J).EQ.0) GO TO 10                                         DEP01911
      DEPR (J,N) = B(1)/NYRD(J)                                         DEP01920
   41 CONTINUE                                                          DEP01930
      DEPR (J,1) = 0.5 * DEPR (J,1)                                     DEP01940
      N = NK + 1                                                        DEP01950
      DEPR (J,N) = DEPR (J,1)                                           DEP01960
   10 CONTINUE                                                          DEP01970
      RETURN                                                            DEP01980
      END                                                               DEP01990
```

Subroutine ECO

```
      SUBROUTINE ECO                                                    ECO00010
C                                                                       ECO00020
C *** THIS SUBROUTINE SUMMARIZES AND PRINTS OUT ESTIMATED FUTURE ANNUAL ECO00030
C ***   CASH FLOWS AND PRESENT VALUE OF CASH FLOWS FOR EACH ALTERNATIVE,ECO00040
C ***   (PART 1 OF OUTPUT).                                             ECO00050
C                                                                       ECO00060
      COMMON/ALL/AFMC(10),AHHV(10),AWRU(10),AXFT(10),                   ECO00070
     +  BTUR(10),DISR(10),EBTU(10),FATS(10),                            ECO00080
     +  HHVU(10),HRAF(10),HRRF(10),IVST(10),NYRS(10),PVAT(10),PCT(10),  ECO00090
     +  RAVL(10),RECY(10),TAUX(10),TRES(10),DEPR(10,20),                ECO00100
     +  NALT,NOP1,NYRD(10)                                              ECO00110
      COMMON/ECO1/CSAL(10),IEXP(10),ITCR(10),                           ECO00120
     +  TXRT(10),WCRQ(10),ACST(10,20),ANCF(10,20),BNCF(10,20),          ECO00130
     +  VCST(10,20),FCST(10,20),CMMB(10,20),AZER(10),                   ECO00140
     +  PAXF(10,20),RCST(10,20),RVAL(10,20),WCRA(10,21),                ECO00150
     +  WCRT(10,21),TITL(20,10),                                        ECO00160
      REAL IVST,ITCR,IEXP                                               ECO00170
C                                                                       ECO00180
      IF (NOP1.NE.1) WRITE (6,11)                                       ECO00190
   11 FORMAT ('1','PART I.  FINANCIAL SUMMARIES')                       ECO00200
      DO 8 J=1,NALT                                                     ECO00210
      MYRS = NYRS(J)                                                    ECO00220
      DO 1 N=1,MYRS                                                     ECO00230
C *** CALCULATE ANNUAL WOOD-BARK FUEL COSTS                             ECO00240
      RCST(J,N) = RVAL(J,N) * TRES(J)                                   ECO00250
C *** CALCULATE ANNUAL ALT/AUX FUEL COSTS                               ECO00260
      ACST(J,N) = PAXF(J,N) * TAUX(J)                                   ECO00270
C *** CALCULATE BEFORE TAX NET EXPENSES AND AVG. COST/MMBTU             ECO00280
      BNCF(J,N)=(VCST(J,N)+FCST(J,N)+RCST(J,N)+ACST(J,N)+DEPR(J,N))     ECO00290
      CMMB(J,N)=BNCF(J,N)/BTUR(J)                                       ECO00300
C *** CALCULATE AFTER TAX NET CASH FLOW                                 ECO00310
      ANCF(J,N) = -(VCST(J,N) + FCST(J,N) +                             ECO00320
     + RCST(J,N) + ACST(J,N)) * (1.0 - TXRT(J)) + DEPR(J,N) * TXRT(J) - ECO00330
     + WCRA(J,N)                                                        ECO00340
    1 CONTINUE                                                          ECO00350
      ANCF(J,1) = ANCF(J,1) + ITCR(J)                                   ECO00360
      N = NYRS(J)                                                       ECO00370
      ANCF(J,N) = ANCF(J,N) + FATS(J) + WCRT(J,N)                       ECO00390
      PCT(J)    = DISR(J)   * 100.0                                     ECO00400
      PVAT(J)=(-IVST(J))-WCRQ(J)+CSAL(J)-(IEXP(J)*(1.0-TXRT(J)))        ECO00420
      AZER(J)=PVAT(J)                                                   ECO00430
      DO 2 N=1,MYRS                                                     ECO00440
C *** CALCULATE PRESENT VALUE AFTER TAXES                               ECO00470
      PVAT(J) = PVAT(J) + ANCF(J,N) /((1.0 + DISR(J))**N)               ECO00480
    2 CONTINUE                                                          ECO00490
C                                                                       ECO00500
C *** PRINTOUT FINANCIAL SUMMARY                                        ECO00510
      IF (NOP1.EQ.1) GO TO 7                                            ECO00520
C *** WRITE INVESTMENT COST PARAMETERS                                  ECO00530
      IF (J.EQ.1) WRITE(6,333) J                                        ECO00540
  333 FORMAT('0',///'0FINANCIAL SUMMARY--ALTERNATIVE',1X,I2/)           ECO00550
      IF (J.GT.1) WRITE(6,33) J                                         ECO00560
   33 FORMAT ('1FINANCIAL SUMMARY--ALTERNATIVE',1X,I2/)                 ECO00570
       WRITE(6,3) (TITL(I,J),I=1,20),NYRS(J),FATS(J),IVST(J),TXRT(J),   ECO00580
     +IEXP(J),WCRQ(J),EBTU(J),CSAL(J),BTUR(J),AXFT(J)                   ECO00590
    3 FORMAT(' ',20A4//1X,'INVESTMENT PARAMETERS (YEAR 0):',8X,'ENDING NECO00600
     +ET SALVAGE (YEAR ',I2,')$',F10.0/ 2X,'DEPRECIABLE ASSETS - - - $',ECO00610
     +F10.0,2X,'EFFECTIVE ANNUAL TAX RATE - - - -',F6.3/2X,'NONDEPREC. EECO00620
     +XPENSES- - - $',F10.0,2X,'HEAT ENERGY REQUIREMENTS AND OUTPUT:'/  ECO00630
     +2X,'WORKING CAPITAL- - - - - $',F10.0,3X,'ESSENTIAL REQ. - - ',F10ECO00640
     +.0,1X,'MMBTU/YR.'/2X,'OLD FACILITY NET SALV. - $',F10.0,3X,'TOTAL ECO00650
     +OUTPUT - - - ',F10.0,' MMBTU/YR.'///1X,'ANNUAL COSTS, DEPRECIATIONECO00660
     + AND AVERAGE ANNUAL'/2X,'COST PER MMBTU OF TOTAL ENERGY OUTPUTS'//ECO00670
     +17X,'FUEL COSTS',9X,'OTHER VAR.',4X,'FIXED',7X,'DEPRE-',5X,'COST/'ECO00671
     +/11X,'WOOD-BARK',6X,A4,8X,'COSTS',7X,'COSTS',7X,'CIATION',4X,'MMBTECO00672
     +U'/15X,4('$',11X),'$',11X,'$')                                    ECO00673
C *** WRITE ANNUAL CASH FLOWS AND DEPRECIATION                          ECO00730
      DO 44 N=1,MYRS                                                    ECO00740
      WRITE(6,4) (N,RCST(J,N),ACST(J,N),VCST(J,N),FCST(J,N),DEPR(J,N),  ECO00750
     +CMMB(J,N))                                                        ECO00760
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   44 CONTINUE                                                           EC000770
    4 FORMAT(' ',1X,'YEAR',1X,I2,5(2X,F10.0),2X,F8.2)                    EC000780
C *** WRITE NET CASH FLOWS, INVESTMENT TAX CREDIT (END OF YEAR VALUES).  EC000790
C ***                                                                   EC000800
      WRITE(6,5) (IEXR(J),AZER(J),BNCF(J,1),TTCR(J),WCRA(J,1),ANCF(J,1))EC000810
    5 FORMAT('0'/1X,'BEFORE TAX NET EXPENSES, INVESTMENT TAX CREDIT, ADDEC000820
     +ITIONAL INVESTMENT (WORKING'/2X,'CAPITAL) AND AFTER TAX NET CASH FEC000821
     +LOW INCLUDING SALVAGE (END OF YEAR VALUES):'//                    EC000822
     +16X,'BEFORE TAX',6X,'TAX',6X,'ADDITIONAL',6X,'AFTER TAX'/         EC000830
     +15X,'NET EXPENSES',4X,'CREDIT',4X,'INVESTMENT',4X,'NET CASH FLOW'/EC000840
     +21X,'$',11X,'$',11X,'$',15X,'$'/                                  EC000850
     +1X,'YEAR  0',6X,F12.0,27X,F12.0/                                  EC000851
     +1X,'YEAR  1',6X,F12.0,F11.0,2X,F11.0,3X,F12.0)                    EC000860
      DO 55 N=2,MYRS                                                    EC000870
      WRITE(6,66) (N,BNCF(J,N),WCRA(J,N),ANCF(J,N))                     EC000880
   55 CONTINUE                                                          EC000890
   66 FORMAT(1X,'YEAR',1X,I2,6X,F12.0,13X,F11.0,3X,F12.0)               EC000900
C *** WRITE PRESENT VALUE OF CASH FLOWS                                 EC000910
      WRITE(6,6) PVAT(J),PCT(J)                                         EC000920
    6 FORMAT('0'/1X,'PRESENT VALUE (YEAR 0) OF AFTER TAX NET CASH FLOWS:EC000930
     +'//6X,'$',F10.0,2X,'AT',1X,F4.1,' PERCENT ANNUAL DISCOUNT RATE')  EC000940
    7 CONTINUE                                                          EC000980
    8 CONTINUE                                                          EC000990
      RETURN                                                            EC001000
      END                                                               EC001010
```

Subroutine EQ1

```
      SUBROUTINE EQ1(A,B)                                               EQ100010
C                                                                       EQ100020
C *** THIS SUBROUTINE EQUATES TEN-ELEMENT ARRAYS - ARGUMENTS A AND B    EQ100030
C                                                                       EQ100040
      DIMENSION A(10),B(10)                                             EQ100050
C                                                                       EQ100060
      DO 1 J=1,10                                                       EQ100070
      A(J) = B(J)                                                       EQ100080
    1 CONTINUE                                                          EQ100090
      RETURN                                                            EQ100100
      END                                                               EQ100110
```

Subroutine HTR

```
      SUBROUTINE HTR                                                    HTR00010
C                                                                       HTR00020
C *** THIS SUBROUTINE CALCULATES APPROXIMATE AVG. HEAT RECOVERY FROM    HTR00030
C ***   WOOD OR BARK FUELS, IN BTU PER POUND 'WET' (AS FIRED) BASED     HTR00040
C ***   ON INPUT DATA AND ASSUMPTIONS.                                  HTR00050
C                                                                       HTR00060
      COMMON/ALL/AFMC(10),AHHV(10),AWRU(10),AXFT(10),                   HTR00070
     +  BTUR(10),DISR(10),EBTU(10),FATS(10),                            HTR00080
     +  HHVU(10),HRAF(10),HRRF(10),IVST(10),NYRS(10),PVAT(10),PCT(10),  HTR00090
     +  PAVL(10),RECY(10),TAUX(10),TRES(10),DEPR(10,20),                HTR00100
     +  NALT,NOP1,NYRD(10)                                              HTR00110
      COMMON/HTP1/ACHL(10),AEAF(10),ASGT(10),ATCA(10),                  HTR00120
     +  ATRF(10),AVCC(10),AVHC(10),AVNC(10),AVOC(10),                   HTR00130
     +  CONV(10),SGHD(10),SGHW(10),                                     HTR00140
C                                                                       HTR00150
      DO 1 J = 1, NALT                                                  HTR00160
C *** CALCULATE HEAT ENERGY PER 'WET' POUND OF FUEL                     HTR00170
C *** CALCULATE STACK GAS-HEAT LOSS CAUSED BY FUEL MOISTURE AND WATER   HTR00180
C ***   FROM HYDROGEN COMBUSTION                                        HTR00190
      SGHW(J)= (970.0 + (212.0 - ATRF(J)) + (0.46 * (ASGT(J) - 212.0))) HTR00200
     +* (AFMC(J) + 9.0 * AVHC(J) * (1.0 - AFMC(J)))                     HTR00210
C *** CALCULATE STACK GAS HEAT LOSS CAUSED BY DRY GAS AND EXCESS AIR    HTR00220
      SGHD(J) = (ASGT(J) - ATCA(J)) * (1.0 - AFMC(J)) * (0.24 * (((AVHC(HTR00230
     +J) * 8.0) + AVCC(J) * 2.667 - AVOC(J)) / 0.232) + AEAF(J) + ((((AVHHTR00240
     +HC(J) * 8.0) + AVCC(J) * 2.667 - AVOC(J)) / 0.232) * 0.768 + AVNC(HTR00250
     +J)) * 0.25 + AVCC(J) * 3.667 * 0.22)                              HTR00260
C *** CALCULATE 'CONVENTIONAL' HEAT LOSSES (RADIATION, CONVECTION, ETC.)HTR00270
      CONV(J) = AHHV(J) * (1.0 - AFMC (J)) * ACHL(J)                    HTR00280
C *** CALCULATE HEAT RECOVERY - BTU / POUND 'WET' WOOD OR BARK FUEL     HTR00290
      RECY(J) = AHHV(J) * (1.0 - AFMC(J)) - (SGHW(J) + SGHD(J)+ CONV(J))HTR00300
      IF(RECY(J).LE.0.0001) RECY(J)=0.0001                              HTR00310
    1 CONTINUE                                                          HTR00320
      RETURN                                                            HTR00330
      END                                                               HTR00340
```

Subroutine PHY

```
      SUBROUTINE PHY                                                    PHY00010
C                                                                       PHY00020
C *** THIS SUBROUTINE CONSOLIDATES AND PRINTS OUT DATA RELATED TO THE   PHY00030
C *** PHYSICAL PARAMETERS (FUEL VOLUME REQUIREMENTS, HEATING VALUE,     PHY00040
C *** WEIGHT, MOISTURE CONTENT) AND HEAT ENERGY REQUIREMENTS--FUEL      PHY00050
C *** SUPPLY BALANCE, IN BRITISH AND SI UNITS (SYSTEME INTERNATIONAL    PHY00060
C *** D'UNITES)                                                         PHY00070
C                                                                       PHY00080
      COMMON/ALL/AFMC(10),AHHV(10),AWPU(10),AXFT(10),                   PHY00090
     + BTUR(10),DISR(10),FBTU(10),FATS(10),                             PHY00100
     + HHVU(10),HRAF(10),HRRF(10),IVST(10),NYRS(10),PVAT(10),PCT(10),   PHY00110
     + RAVL(10),RECY(10),TAUX(10),TRES(10),DEPR(10,20),                 PHY00120
     + NALT,NOP1,NYRD(10)                                               PHY00130
      COMMON/PHY1/ABTU(10),AFSU(10),AFWR(10),ASSI(10),                  PHY00140
     + PCTA(10),PCTR(10),RBTU(10),RCOD(10),RDSI(10),                    PHY00150
     + RFS1(10),RFS2(10),PHSI(10),PSSI(10),SBTU(10),                    PHY00160
      DIMENSION DWMC(10)                                                PHY00170
C                                                                       PHY00180
      DO 1 J=1,NALT                                                     PHY00190
C *** CALCULATE DRY WEIGHT MOISTURE CONTENT                             PHY00200
      DWMC(J) = AFMC(J)/(1.0 - AFMC(J))                                 PHY00210
C *** CALCULATE MMBTU SUPPLIED BY WOOD OR BARK FUEL                     PHY00220
      RBTU(J)=TRES(J)*HRRF(J)                                           PHY00230
C *** CALCULATE MMBTU SUPPLIED BY AUX-ALT FUEL                          PHY00240
      ABTU(J)=TAUX(J)*HRAF(J)                                           PHY00250
C *** CALCULATE PCT. TOTAL HEAT SUPPLIED BY WOOD OR BARK FUEL           PHY00260
      PCTR(J)=(RBTU(J)/(RBTU(J)+ABTU(J)))*100.0                         PHY00270
C *** CALCULATE PCT. TOTAL HEAT SUPPLIED BY AUX/ALT FUEL                PHY00280
      PCTA(J)=(ABTU(J)/(RBTU(J)+ABTU(J)))*100.0                         PHY00290
C *** CALCULATE AVG. AS-FIRED WEIGHT OF WOOD OR BARK FUEL/SALES UNIT    PHY00300
      AFWR(J)=AWPU(J)/(1.0-AFMC(J))                                     PHY00310
C *** CALCULATE RECOVERABLE HEAT IN BTU'S PER OVENDRY POUND             PHY00320
      RCOD(J)=RECY(J)/(1.0-AFMC(J))                                     PHY00330
C *** CALCULATE RECOVERABLE HEAT IN KJOULES/KG. AS-FIRED                PHY00340
      PHSI(J)=RECY(J)*2.3278                                            PHY00350
      RDSI(J)=RCOD(J)*2.3278                                            PHY00360
C *** CALCULATE RECOVERABLE HEAT IN KJOULES/KG. OVENDRY                 PHY00370
C *** CALCULATE RECOVERABLE HEAT IN BILLION JOULES PER RESIDUE FUEL     PHY00380
C *** SALES UNIT                                                        PHY00390
      PSSI(J)=HRRF(J)*2.3278                                            PHY00400
C *** CALCULATE RECOVERABLE HEAT IN BILLION JOULES PER AUX-ALT FUEL     PHY00410
C *** SALES UNIT                                                        PHY00420
      ASSI(J)=HRAF(J)*2.3278                                            PHY00430
    1 CONTINUE                                                          PHY00440
C *** TABLE 1 OUTPUT AND FORMAT                                         PHY00450
      WRITE (6,11)                                                      PHY00460
   11 FORMAT('1','PART III. DESCRIPTION OF ENERGY BALANCE AND FUEL PARAMPHY00470
     +ETERS'/11X,'FOR EACH ALTERNATIVE  (TABLES 1 TO 4)'//2X,'TABLE 1.--PHY00480
     +HEAT ENERGY BALANCE AND FUEL REQUIREMENTS (ANNUAL BASIS)',        PHY00490
     + //9X,'ESSENTIAL ENERGY',3X,'SURPLUS ENERGY',4X,'TOTAL ENERGY',   PHY00500
     + /11X,'REQUIREMENTS',6X,'REQUIREMENTS',8X,'OUTPUT'/13X,           PHY00510
     +'(MMBTU)',11X,'(MMBTU)',10X,'(MMBTU)'/)                           PHY00520
      WRITE(6,2) (J,FBTU(J),SBTU(J),BTUR(J),J=1,NALT)                   PHY00530
    2 FORMAT(' ALT',I2,1X,F16.0,2X,F16.0,1X,F16.0)                      PHY00540
      WRITE(6,22)                                                       PHY00550
   22 FORMAT('0'/7X,'ENERGY SUPPLIED BY',11X,'ENERGY SUPPLIED BY OTHER OPHY00560
     +R'/8X,'WOOD-BARK FUEL',3X,'(PCT. OF',6X,'AUXILIARY FUEL',3X,      PHY00570
     +'(PCT. OF'/14X,'(MMBTU)',5X,'TOTAL)',12X,'(MMBTU)',6X,'TOTAL)'/)  PHY00580
      WRITE(6,23) (J,RBTU(J),PCTR(J),ABTU(J),PCTA(J),J=1,NALT)          PHY00590
   23 FORMAT(' ALT',I2,F16.0,4X,F5.1,4X,F16.0,6X,F5.1)                  PHY00600
      WRITE (6,33)                                                      PHY00610
   33 FORMAT('0'/10X,'QUANTITY OF',9X,'WOOD-BARK FUEL',9X,'OTHER FUEL'/ PHY00620
     +7X,'WOOD-BARK AVAILABLE',5X,'REQUIREMENTS',9X,'REQUIREMENTS'/)    PHY00630
      WRITE(6,3) (J,RAVL(J),RFS1(J),RFS2(J),TRES(J),RFS1(J),RFS2(J),    PHY00640
     +TAUX(J),AFSU(J),AXFT(J),J=1,NALT)                                 PHY00650
    3 FORMAT(' ALT',I2,2X,F10.0,1X,2A4,F12.0,1X,2A4,F12.0,1X,A4,1X,'(', PHY00660
     +A4,')')                                                           PHY00670
C *** TABLE 2 OUTPUT AND FORMAT                                         PHY00680
      WRITE (6,44)                                                      PHY00690
   44 FORMAT('0'//2X,'TABLE 2.--WOOD-BARK FUEL PARAMETERS AND ESTIMATED PHY00700
     +HEAT RECOVERY'//6X,'OVENDRY WT (LBS)',3X,'MOISTURE CONT.',5X,'WET PHY00710
     +WT (LBS)',4X,'MOISTURE CONT.'/7X,'PER SALES UNIT',4X,'(DRY WT BASIPHY00720
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      +S)',4X,'PER SALES UNIT',3X,'(WET WT BASIS)'/)                    PHY00730
       WRITE (6,4) (J,AWRU(J),RFS1(J),RFS2(J),DWMC(J),AFWR(J),RFS1(J),    PHY00740
      +RFS2(J),AFMC(J),J=1,NALT)                                          PHY00750
     4 FORMAT(' ALT',I2,2X,F6.0,'/',2A4,8X,F4.2,8X,F6.0,'/',2A4,8X,F4.2) PHY00760
                                                                          PHY00770
       WRITE (6,55)                                                       PHY00780
    55 FORMAT('0'/6X,'HIGHER HEAT VALUE',' - - - - - ESTIMATED HEAT ENERGPHY00790
      +Y RECOVERY',5(' -')/                                               PHY00800
      +8X,'(BTU/DRY LB)',4X,'(BTU/DRY LB)',2X,'(BTU/WET LB)',6X,'(MMBTU/SPHY00810
      +ALES UNIT)'/)                                                      PHY00820
       WRITE(6,5) (J,AHHV(J),RCOD(J),RECY(J),RPPF(J),RFS1(J),RFS2(J),     PHY00830
      +J=1,NALT)                                                          PHY00840
     5 FORMAT(' ALT',I2,6X,F6.0,10X,F6.0,8X,F6.0,4X,F12.3,'/',2A4)       PHY00850
C *** TABLES 3 AND 4 OUTPUT AND FORMAT                                    PHY00860
       WRITE (6,66)                                                       PHY00870
    66 FORMAT ('1'/////       2X,'TABLE 3.--OTHER OR AUXILIARY FUEL PARAMEPHY00880
      +TERS'//7X,'TYPE OF',3X,'HIGHER HEAT VALUE',3X,                     PHY00890
      +'ESTIMATED HEAT RECOVERY'/8X,'FUEL',10X,'(MMBTU)',17X,'(MMBTU)'//)PHY00900
       WRITE (6,6) (J,AXFT(J),HHVU(J),AFSU(J),HRAF(J),AFSU(J),J=1,NALT)  PHY00910
     6 FORMAT (' ALT',I2,2X,A4,6X,F8.2,'/',A4,12X,F8.2,'/',A4)           PHY00920
       WRITE (6,77)                                                       PHY00930
    77 FORMAT ('0'///2X,'TABLE 4.--INTERNATIONAL SYSTEM (SI) UNIT RECOVERPHY00940
      +ABLE HEAT ENERGY ESTIMATES'//                                      PHY00950
      +9X,6('- '),'ENERGY IN WOOD-BARK FUEL',9(' -'),'OTHER FUEL - -'/   PHY00960
      +10X,'(KJOULE/KG',6X,'(KJOULE/KG',6X,'(BILLION JOULE',6X,'(BILLION PHY00970
      +JOULE'/                                                            PHY00980
      +10X,'DRY BASIS)',6X,'WET BASIS)',6X,'PER SALES UNIT)',5X,'PER SALEPHY00990
      +S UNIT)'/)                                                         PHY01000
       WRITE (6,7) (J,RDSI(J),RWSI(J),RSSI(J),RFS1(J),RFS2(J),ASSI(J),    PHY01010
      +AFSU(J),J=1,NALT)                                                  PHY01020
     7 FORMAT(' ALT',I2,4X,F8.0,8X,F8.0,4X,F9.1,'/',2A4,5X,F9.1,'/',A4)  PHY01030
       WRITE(6,8)                                                         PHY01040
     8 FORMAT('1','END OF OUTPUT')                                        PHY01050
       RETURN                                                             PHY01060
       END                                                                PHY01070
```

Subroutine RAN

```
       SUBROUTINE RAN(DAT,NRK,NALT)                                       RAN00010
C                                                                         RAN00020
C *** THIS SUBROUTINE RANKS ELEMENTS IN THE ARRAY (DAT) BY NUMERICAL      RAN00030
C *** MAGNITUDE, AND CREATES THE INTEGER ARRAY (NRK) WHICH IS THE ORDER   RAN00040
C *** OF MAGNITUDE OF ELEMENTS                                            RAN00050
C                                                                         RAN00060
       DIMENSION DAT(10),NRK(10),DATA(10)                                 RAN00070
C                                                                         RAN00080
       CALL EQ1(DATA,DAT)                                                 RAN00090
       NRK(1)=1                                                           RAN00100
       KK=1                                                               RAN00110
       DO 2 J=1,NALT                                                      RAN00120
       DO 1 K=1,NALT                                                      RAN00130
       IF(DATA(K).GT.DATA(KK)) NRK(J)=K                                   RAN00140
       IF(DATA(K).GT.DATA(KK)) KK=K                                       RAN00150
     1 CONTINUE                                                           RAN00160
       DATA(KK)=(-10.0)*(10.0**20.0)                                      RAN00170
     2 CONTINUE                                                           RAN00180
       RETURN                                                             RAN00190
       END                                                                RAN00200
```

Subroutine RD1

```
       SUBROUTINE RD1 (V,NYRS,NALT)                                       RD100010
C                                                                         RD100020
C *** THIS SUBROUTINE READS ANNUAL CASH FLOW AND PRICE INPUT DATA.        RD100030
C ***   ANNUAL ESTIMATES MAY BE READ IN, OR ALTERNATIVELY THE FIRST       RD100040
C ***   YEAR ESTIMATE PLUS ANNUAL RATE OF INCREASE WILL BE READ IN.       RD100050
C                                                                         RD100060
       DIMENSION V(10,20),NYRS(10)                                        RD100070
C                                                                         RD100080
       DO 3 J=1,NALT                                                      RD100090
       RI = 0.0                                                           RD100100
       READ (5,4) (V(J,N),N=1,10)                                         RD100110
       IF(V(J,2).LT.1.0.AND.V(J,2).GT.0.00001) RI = V(J,2)                RD100120
       IF(V(J,2).LT.1.0.AND.V(J,2).GT.0.00001) GO TO 1                    RD100130
```

```
      IF(NYRS(J).LE.10) GO TO 3                                         RD100140
      READ (5,4) (V(J,N),N=11,20)                                       RD100150
      IF(V(J,2).GE.1.0.OR.V(J,2).LE.0.0) GO TO 3                        RD100160
    1 CONTINUE                                                          RD100170
      NY = NYRS(J)                                                      RD100180
      DO 2 N=2,NY                                                       RD100190
      K = N - 1                                                         RD100200
      V(J,N) = V(J,K) * (1.0 + RI)                                      RD100210
    2 CONTINUE                                                          RD100220
    3 CONTINUE                                                          RD100230
    4 FORMAT(10F8)                                                      RD100240
      RETURN                                                            RD100250
      END                                                               RD100260
```

Subroutine REQ

```
      SUBROUTINE REQ                                                    REQ00010
C                                                                       REQ00020
C *** THIS SUBROUTINE CALCULATES HEAT RECOVERY AND VOLUME REQUIREMENTS  REQ00030
C ***   FOR WOOD OR BARK AND AUXILIARY OR ALTERNATE FUELS PER SALES UNITREQ00040
C                                                                       REQ00050
      COMMON/ALL/AFMC(10),AHHV(10),AWRU(10),AXFT(10),                   REQ00060
     +  BTUR(10),DISR(10),EBTU(10),FATS(10),                            REQ00070
     +  HHVU(10),HRAF(10),HRRF(10),IVST(10),NYRS(10),PVAT(10),PCT(10),  REQ00080
     +  RAVL(10),RECY(10),TAUX(10),TRES(10),DEPR(10,20),                REQ00090
     +  NALT,NOP1,NYRD(10)                                              REQ00100
      COMMON/REQ1/AFBA(10),CHRE(10),                                    REQ00110
      DO 1 J=1,NALT                                                     REQ00120
C *** CALCULATE HEAT RECOVERY IN MILLION BTU PER SALES UNIT             REQ00130
C ***   WOOD OR BARK FUEL                                               REQ00140
      HRRF(J) = (AWRU(J) / (1.0 - AFMC(J)) * RECY(J) / (10.0**6))       REQ00150
C *** CALCULATE HEAT RECOVERY IN MILLION BTU PER SALES / VALUE UNIT     REQ00160
C ***   AUXILARY OR ALTERNATE FUEL                                      REQ00170
      HRAF(J) = HHVU(J) * CHRE(J)                                       REQ00180
C *** CALCULATE TOTAL SALES UNITS OF WOOD OR BARK FUEL REQUIRED         REQ00190
      TRES(J) = BTUR(J) * AFBA(J) / HRRF(J)                             REQ00200
C *** CALCULATE TOTAL SALES UNITS OF AUXILIARY OR ALT. FUEL REQUIRED    REQ00210
      TAUX(J) = BTUR(J) * (1.0 - AFBA(J)) / HRAF(J)                     REQ00220
      IF(TRES(J).GT.RAVL(J)) TAUX(J) = TAUX(J) + (TRES(J) - RAVL(J)) * HREQ00230
     +RRF(J) / HRAF(J)                                                  REQ00240
      IF(TRES(J).GT.RAVL(J)) TRES(J) = RAVL(J)                          REQ00250
    1 CONTINUE                                                          REQ00260
      RETURN                                                            REQ00270
      END                                                               REQ00280
```

Subroutine RNK

```
      SUBROUTINE RNK                                                    RNK00010
C                                                                       RNK00020
C *** THIS SUBROUTINE RANKS ECONOMIC ALTERNATIVES ACCORDING TO HIGHEST  RNK00030
C ***   BENEFIT COST RATIO OF ESSENTIAL (PROCESS) HEAT REQUIREMENTS     RNK00040
C ***   AND HIGHEST BENEFIT COST RATIO OF TOTAL HEAT REQUIREMENTS.      RNK00050
      REAL IVST,IEXP                                                    RNK00060
      COMMON/ALL/AFMC(10),AHHV(10),AWRU(10),AXFT(10),                   RNK00070
     +  BTUR(10),DISR(10),EBTU(10),FATS(10),                            RNK00080
     +  HHVU(10),HRAF(10),HRRF(10),IVST(10),NYRS(10),PVAT(10),PCT(10),  RNK00090
     +  RAVL(10),RECY(10),TAUX(10),TRES(10),DEPR(10,20),                RNK00100
     +  NALT,NOP1,NYRD(10)                                              RNK00110
      COMMON/RNK1/DAT1(10),DAT2(10),HVAL(10,20),                        RNK00120
     +  NRK1(10),NRK2(10),SVAL(10,20),                                  RNK00130
      COMMON/ECO1/CSAL(10),IEXP(10),ITCR(10),TXRT(10),                  RNK00131
     +  WCRQ(10),ACST(10,20),ANCF(10,20),BNCF(10,20),                   RNK00132
     +  VCST(10,20),FCST(10,20),CMMB(10,20),AZER(10),                   RNK00133
     +  RAXF(10,20),RCST(10,20),RVAL(10,20),WCRA(10,21),                RNK00134
     +  WCRT(10,21),TITL(20,10),                                        RNK00135
      COMMON/PHY1/ABTU(10),AFSU(10),AFWR(10),ASSI(10),                  RNK00130
     +  PCTA(10),PCTR(10),RBTU(10),RCOD(10),RDSI(10),                   RNK00132
     +  RFS1(10),RFS2(10),RHSI(10),RSSI(10),SBTU(10)                    RNK00133
      DIMENSION BCAT(10),BCAE(10)                                       RNK00150
C *** CALCULATE, FOR EACH ALTERNATIVE, THE BENEFIT COST RATIO           RNK00170
C *** (RATIO OF PRESENT VALUE OF OUTPUT TO PRESENT VALUE OF COST)       RNK00180
      DIMENSION RVST(10)                                                RNK00190
      DO 2 J=1,NALT                                                     RNK00200
      DAT1(J)=0.0                                                       RNK00210
      DAT2(J)=0.0                                                       RNK00220
      NY=NYRS(J)                                                        RNK00250
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```
C *** CALCULATE PRESENT VALUE OF ENERGY OUTPUT                            RNK00260
C *** FOR ESSENTIAL AND TOTAL HEAT REQUIREMENTS.                          RNK00270
      DO 1 N=1,NY                                                         RNK00280
      DAT1(J)=DAT1(J)+(HVAL(J,N)*EBTU(J))/((1.0+DISR(J))**N)              RNK00290
      DAT2(J)=DAT2(J)+(HVAL(J,N)*EBTU(J)+SVAL(J,N)*SBTU(J))/((1.0+DISR(JRNK00300
     +))**N)                                                              RNK00301
    1 CONTINUE                                                            RNK00310
C *** CALCULATE BENEFIT COST RATIO (RATIO OF RRESENT VALUE OF ENERGY      RNK00380
C *** OUTPUTS TO PRESENT VALUE OR COSTS OF HEAT ENERGY REQUIREMENTS)      RNK00390
C ***                                                                     RNK00400
      BCAE(J)=-DAT1(J)/PVAT(J)                                            RNK00410
      BCAT(J)=-DAT2(J)/PVAT(J)                                            RNK00420
      RVST(J) = (IVST(J) + IEXP(J) + WCRQ(J)) - CSAL(J)                   RNK00421
    2 CONTINUE                                                            RNK00450
      IF(NOP1.EQ.1) GO TO 13                                              RNK00460
C *** RANKING OF ALTERNATIVES BY HIGHEST BENEFIT COST RATIO OF HEAT       RNK00470
      CALL RAN(BCAE,NRK1,NALT)                                            RNK00500
      CALL RAN(BCAT,NRK2,NALT)                                            RNK00520
C *** RRINT OUT USER SPECIFIED HEAT ENERGY VALUE($/MMBTU)                  RNK00530
      WRITE(6,3)                                                          RNK00540
    3 FORMAT('1',2X,'PART II.  BENEFIT COST RATIOS FOR ALL ALTERNATIVES'RNK00550
     +///4X,'FIRST YEAR HEAT ENERGY VALUES (USER SPECIFIED) AND DISCOUNTRNK00551
     +ED'/4X,'PRESENT VALUE OF HEAT ENERGY FOR EACH ALTERNATIVE:'//       RNK00552
     +9X,'HEAT ENERGY VALUE ($/MMBTU)',3X,'PRESENT VALUE OF HEAT ENERGY'RNK00553
     +,3X,'DISCOUNT'/10X,'ESSENTIAL',9X,'SURPLUS',4X,'(BASED ON',10X,     RNK00554
     +'(INCLUDING',5X,'RATE'/11X,'ENERGY',11X,'ENERGY',5X,'ESSENTIAL)',  RNK00555
     +10X,'SURPLUS)',4X,'(PCT.)'/)                                        RNK00556
      DO 20 J=1,NALT                                                      RNK00553
      M=1                                                                 RNK00554
      WRITE(6,4) J,HVAL(J,M),SVAL(J,M),DAT1(J),DAT2(J),PCT(J)             RNK00555
    4 FORMAT(4X,'ALT',1X,I2,2X,F6.2,10X,F6.2,4X,F10.0,9X,F10.0,4X,F5.1) RNK00556
   20 CONTINUE                                                            RNK00557
C *** PRINT OUT BENEFIT COST RATIO IN RANKED ORDER OF HIGHEST TO LOWEST RNK00560
C *** VALUE FOR EACH ALTERNATIVE.                                         RNK00565
      WRITE(6,14)                                                         RNK00570
   14 FORMAT(///4X,'RANKING OF ALTERNATIVES BY HIGHEST BENEFIT COST RATIRNK00580
     +O'/4X,'(RATIO OF P.V. OF HEAT ENERGY OUTRUT TO P.V. OF AFTER TAX'/RNK00590
     +4X,'NET CASH FLOW) BASED ON ESSENTIAL HEAT ENERGY REQUIREMENTS:'//RNK00600
     +21X,'B/C RATIO',15X,'REQUIRED NET INVESTMENT'/)                     RNK00601
      DO 5 J=1,NALT                                                       RNK00620
      K = NRK1(J)                                                         RNK00620
      WRITE(6,6) NRK1(J),BCAE(K),RVST(K)                                  RNK00640
    5 CONTINUE                                                            RNK00650
    6 FORMAT(10X,'ALT',1X,I2,2X,F10.2,20X,F10.1)                          RNK00660
      WRITE(6,7)                                                          RNK00670
    7 FORMAT('0'//4X,'RANKING OF ALTERNATIVES BY HIGHEST BENEFIT COST RARNK00680
     +TIO'/4X,'BASED ON TOTAL HEAT ENERGY OUTRUT (INCLUDING SURPLUS):'//RNK00690
     +21X,'B/C RATIO',15X,'REQUIRED NET INVESTMENT'/)                     RNK00691
      DO 8 J=1,NALT                                                       RNK00720
      K = NRK2(J)                                                         RNK00730
      WRITE(6,6) NRK2(J),BCAT(K),RVST(K)                                  RNK00750
    8 CONTINUE                                                            RNK00760
      NB = 0                                                              RNK00780
      DO 9 J=1,NALT                                                       RNK00800
      DIF2 = EBTU(1) - EBTU(J)                                            RNK00830
      IF(DIF2.GT.0.0001.OR.DIF2.LT.-0.0001) NB = 1                        RNK00840
    9 CONTINUE                                                            RNK00870
      IF(NB.EQ.1) WRITE(6,11)                                             RNK00890
   11 FORMAT('0'/4X,'THE RANKINGS BY BENEFIT COST RATIO ARE NOT VALID CRRNK00940
     +ITERIA FOR'/4X,'COMPARISON BECAUSE THE USER HAS SRECIFIED DIFFERENRNK00950
     +T ESSENTIAL'/4X,'HEAT REQUIREMENTS AMONG THE ALTERNATIVES'//)       RNK00960
   13 CONTINUE                                                            RNK01000
      END                                                                 RNK01010
```

Subroutine RUP

```
      =====  RUP  =====

C *** THIS IS THE MAIN SUBROUTINE FOR THE COMPARE PROGRAM.  THE COMPARE RUP00010
C ***   PROGRAM PROVIDES COMPARISON OF ECONOMIC ALTERNATIVES IN SYSTEMS RUP00020
C ***   FOR PROVIDING PROCESS HEAT ENERGY, IN THE CONTEXT OF A FOREST   RUP00030
C ***   RRODUCTS MANUFACTURING FACILITY WITH AVAILABLE WOOD OR BARK     RUP00040
C ***   RESIDUE FUEL.  THE PROGRAM RROVIDES A RANKING OF ALTERNATIVES   RUP00050
C ***   ACCORDING TO THE LOWEST DISCOUNTED BENEFIT COST RATIO.          RUP00060
```

```
C
      REAL IVST,ITCP,IEXP,INRT
      DIMENSION NCAF(10),INPT(10)
      COMMON/ALL/AFMC(10),AHHV(10),AWRU(10),AXFT(10),
     +  BTUR(10),DISR(10),EBTU(10),FATS(10),
     +  HHVU(10),HPAF(10),HRPF(10),IVST(10),NYPS(10),RVAT(10),PCT(10),
     +  RAVL(10),PECY(10),TAUX(10),TPES(10),DEPP(10,20),
     +  NALT,NOP1,NYRD(10)
      COMMON/REQ1/AFBA(10),CHPE(10),
      COMMON/HTR1/ACHL(10),AEAF(10),ASGT(10),ATCA(10),
     +  ATPF(10),AVCC(10),AVHC(10),AVNC(10),AVOC(10),
     +  CONV(10),SGHD(10),SGHW(10),
      COMMON/DEP1/B(21),D(10),NDEP(10),
      COMMON/FCO1/CSAL(10),IEXP(10),ITCR(10),
     +  TXRT(10),WCPQ(10),ACST(10,20),ANCF(10,20),BNCF(10,20),
     +  VCST(10,20),FCST(10,20),CMMR(10,20),AZEP(10),
     +  RAXF(10,20),RCST(10,20),RVAL(10,20),WCPA(10,21),
     +  WCRT(10,21),TITL(20,10),
      COMMON/PHY1/ABTU(10),AFSU(10),AFWR(10),ASSI(10),
     +  PCTA(10),RCTR(10),RBTU(10),RCOD(10),PDSI(10),
     +  RFS1(10),RFS2(10),RHSI(10),RSSI(10),SBTU(10),
      COMMON/PNK1/DAT1(10),DAT2(10),HVAL(10,20),
     +    NRK1(10),NRK2(10),SVAL(10,20)
C
C *** READ STATEMENTS
C
      READ (5,1) NALT
      DO 11 J=1,NALT
      READ (5,2)  (TITL(I,J),I=1,20)
   11 CONTINUE
      DO 22 J=1,NALT
      READ (5,3)  AFMC(J),AWRU(J),RFS1(J),RFS2(J),AVHC(J),AVOC(J),
     +AVCC(J),AVNC(J),AHHV(J),NCAF(J),AXFT(J),AFSU(J),HHVU(J),CHPE(J),
   22 CONTINUE
      DO 33 J=1,NALT
      AFBA(J) = 1.0
      READ (5,4)  EBTU(J),SBTU(J),RAVL(J),ASGT(J),ATRF(J),ATCA(J),
     +AEAF(J),ACHL(J),AFBA(J)
   33 CONTINUE
      DO 44 J=1,NALT
      BTUR(J)=EBTU(J) + SBTU(J)
      READ (5,5)  IVST(J),WCRQ(J),IEXP(J),CSAL(J),FATS(J),DISP(J),
     +TXRT(J),NDEP(J),NYRS(J),NYRD(J),ITCR(J),INRT(J)
   44 CONTINUE
      CALL RD1 (VCST,NYRS,NALT)
      CALL RD1 (FCST,NYRS,NALT)
      CALL RD1 (HVAL,NYRS,NALT)
      CALL RD1 (SVAL,NYRS,NALT)
      CALL RD1 (RAXF,NYRS,NALT)
      CALL RD1 (RVAL,NYRS,NALT)
    1 FORMAT(I2)
    2 FORMAT(20A4)
    3 FORMAT(F5,F6,2A4,4(F5),F6,I1,2A4,F5,F4)
    4 FORMAT(4F10,3F5,2F4)
    5 FORMAT(5F10,2F4,I1,2I2,F9,F6)
    6 FORMAT(10F8)
      DO 7 J=1,NALT
      IF(NDEP(J).NE.9) GO TO 7
      READ (5,6) (DEPP(J,N),N=1,10)
      IF(NYRS(J).LE.10) GO TO 7
      NY = NYRS(J)
      READ (5,6) (DEPP(J,N),N=11,NY)
    7 CONTINUE
C
C *** INITIALIZATION OF STORAGE ARRAYS
C
      NOP1 = 0
      NOP2 = 0
      DO 9 J=1,NALT
      WCPT(J,1) = WCRQ(J) * (1.0 + INRT(J))
      WCRA(J,1) = WCRT(J,1) - WCRQ(J)
      NY = NYPS(J)
      DO 8 N=1,NY
```

```
      NN = N + 1                                                        RUP00810
C *** CALCULATE YEARLY ADDITIONAL WORKING CAPITAL REQUIREMENTS PER YEAR RUP00820
      WCRT(J,NN) = WCRT(J,N) * (1.0 + INPT(J))                          RUP00830
      WCRA(J,NN) = WCRT(J,NN) - WCRT(J,N)                               RUP00840
      ANCF(J,N) = 0.0                                                   RUP00850
    8 CONTINUE                                                          RUP00860
    9 CONTINUE                                                          RUP00870
      DO 10 J=1,NALT                                                    RUP00880
      IF(AVHC(J).LE.0.0) AVHC(J) = 0.06                                 RUP00890
      IF(AVOC(J).LE.0.0) AVOC(J) = 0.41                                 RUP00900
      IF(AVCC(J).LE.0.0) AVCC(J) = 0.50                                 RUP00910
      IF(AVNC(J).LE.0.0) AVNC(J) = 0.01                                 RUP00920
      IF(AHHV(J).LE.0.0) AHHV(J) = 8500.0                               RUP00930
      IF(NCAF(J).EQ.0) AXFT(J) = ' OIL'                                 RUP00940
      IF(NCAF(J).EQ.0) AFSU(J) = 'BBL.'                                 RUP00950
      IF(NCAF(J).EQ.0) HHVU(J) = 6.3                                    RUP00960
      IF(NCAF(J).EQ.0) CHRE(J) = 0.8                                    RUP00970
      IF(NCAF(J).EQ.1) AXFT(J) = 'COAL'                                 RUP00980
      IF(NCAF(J).EQ.1) AFSU(J) = ' TON'                                 RUP00990
      IF(NCAF(J).EQ.1) HHVU(J) = 24.0                                   RUP01000
      IF(NCAF(J).EQ.1) CHRE(J) = 0.67                                   RUP01010
      IF(NCAF(J).EQ.2) AXFT(J) = ' GAS'                                 RUP01020
      IF(NCAF(J).EQ.2) AFSU(J) = ' MCF'                                 RUP01030
      IF(NCAF(J).EQ.2) HHVU(J) = 1.0                                    RUP01040
      IF(NCAF(J).EQ.2) CHRE(J) = 0.76                                   RUP01050
      IF(ASGT(J).LE.0.0) ASGT(J) = 500.0                                RUP01060
      IF(ATRF(J).LE.0.0) ATRF(J) = 60.0                                 RUP01070
      IF(ATCA(J).LE.0.0) ATCA(J) = 60.0                                 RUP01080
      IF(AEAF(J).LE.0.0) AEAF(J) = 0.40                                 RUP01090
      IF(ACHL(J).LE.0.0) ACHL(J) = 0.04                                 RUP01100
   10 CONTINUE                                                          RUP01110
C                                                                       RUP01120
C *** CALL RUP SUBROUTINES                                              RUP01130
C                                                                       RUP01140
      CALL DEP                                                          RUP01150
      CALL HTR                                                          RUP01160
      CALL REQ                                                          RUP01170
      CALL ECO                                                          RUP01180
      CALL RNK                                                          RUP01190
      CALL PHY                                                          RUP01200
                                                                        RUP01210
      STOP                                                              RUP01220
      END                                                               RUP01230
```

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U.S. Forest Products Laboratory

COMPARE—A Method for Analyzing Investment Alternatives in Industrial Wood and Bark Energy Systems, by Peter J. Ince, Madison, Wis., FPL 1982.

28 p. (USDA For. Serv. Gen. Tech. Rep. FPL-36)

A method is presented that was developed to analyze investments in industrial wood and bark energy systems. The method is embedded in a computer program called COMPARE. This program provides complete guidelines for economic analysis of wood and bark energy systems.

Keywords: Investment alternatives, industrial wood, bark energy systems, COMPARE

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AD-A132 111 COMPARE: A METHOD FOR ANALYZING INVESTMENT ALTERNATIVES IN INDUSTRIAL WOOD AND BARK ENERGY SYSTEMS(U) FOREST PRODUCTS LAB MADISON WI P J INCE JUN 83 FSGTR-FPL-36 2/2

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May 1984

Errata

COMPARE:

A Method for
Analyzing Investment
Alternatives in
Industrial Wood and
Bark Energy Systems

In figure 1, page 8, of this publication, the entry written in columns 2 through 9 of lines 8, 9, and 10 of the data input should be

252230.

and not

25230.

as written.

The corrected entries will produce the output as shown in figure 3 of this publication. The uncorrected entries will produce output with different output values than those shown in figure 3.

Ince, Peter J. COMPARE--A Method for Analyzing Investment Alternatives in Industrial Wood and Bark Energy Systems. Gen. Tech. Rep. FPL-36. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory; 1982. 28 p.

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